

Part 1 - Basic Interferometers for Optical Testing

- **Two Beam Interference**
- **Fizeau and Twyman-Green interferometers**
- **Basic techniques for testing flat and spherical surfaces**
- **Mach-Zehnder, Scatterplate, and Smartt Interferometers**
- **Shearing Interferometers**
- **Typical Interferograms**

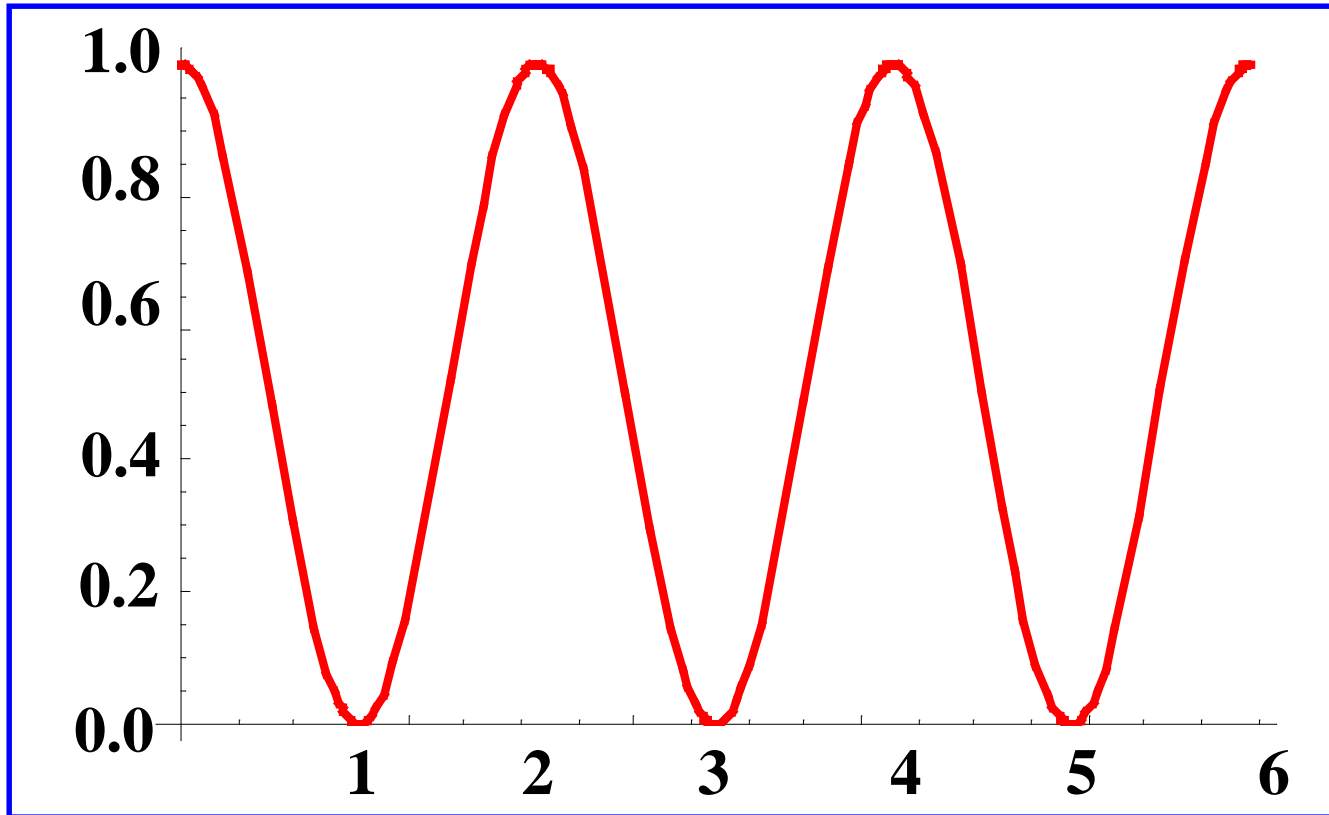
Two-Beam Interference Fringes

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\alpha_1 - \alpha_2)$$

$\alpha_1 - \alpha_2$ is the phase difference between the two interfering beams

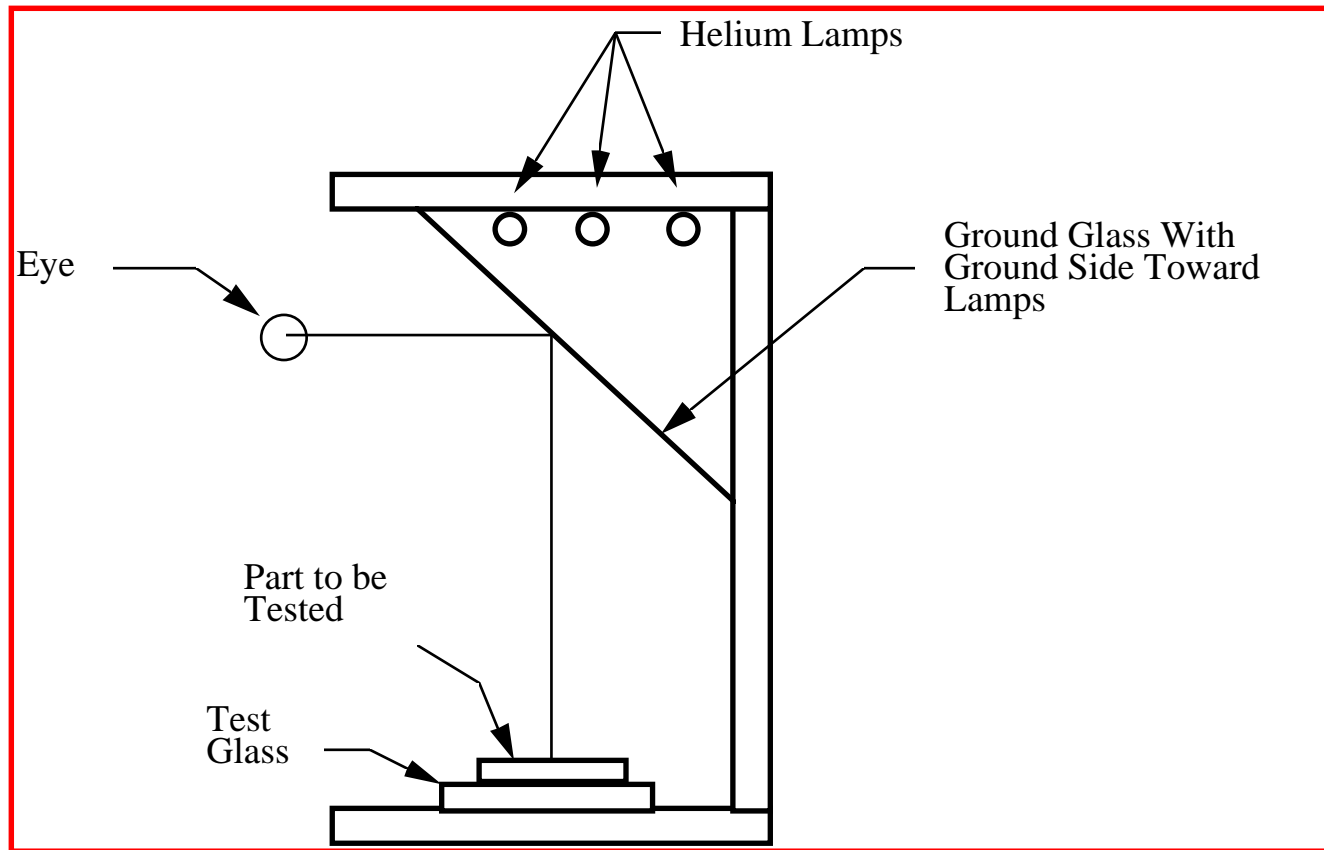
$$\alpha_1 - \alpha_2 = \left(\frac{2\pi}{\lambda}\right)(\text{optical path difference})$$

Sinusoidal Interference Fringes

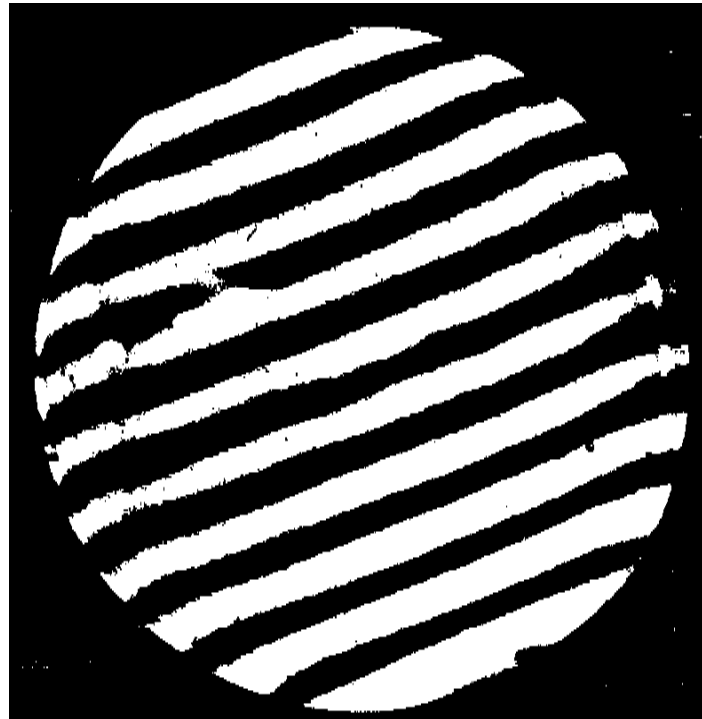


$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\alpha_1 - \alpha_2)$$

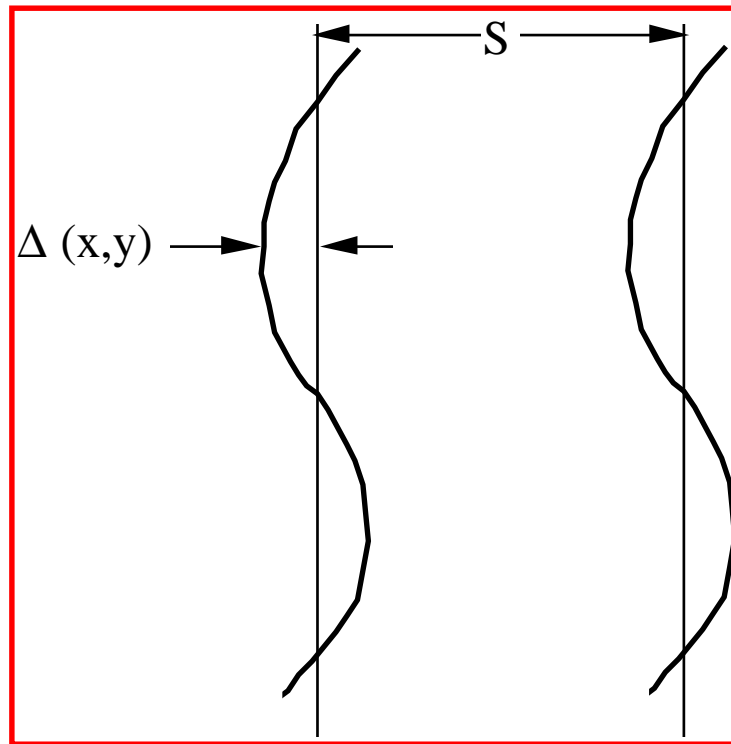
Classical Fizeau Interferometer



Typical Interferogram Obtained using Fizeau Interferometer

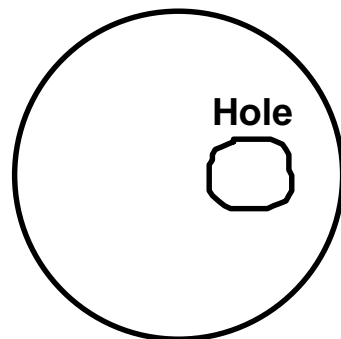


Relationship between Surface Height Error and Fringe Deviation

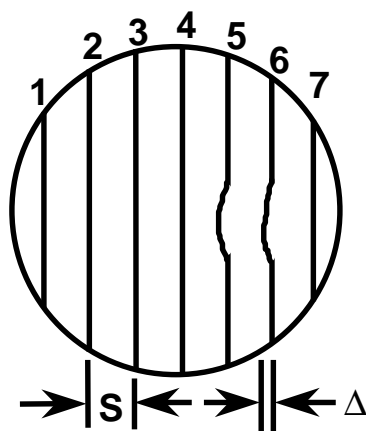
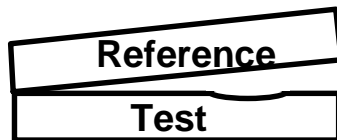


$$\text{Surface height error} = \left(\frac{\lambda}{2}\right)\left(\frac{\Delta}{S}\right)$$

Fizeau Fringes



Top View

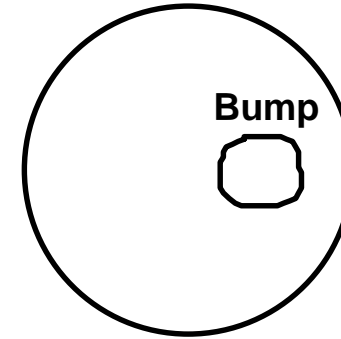


Interferogram

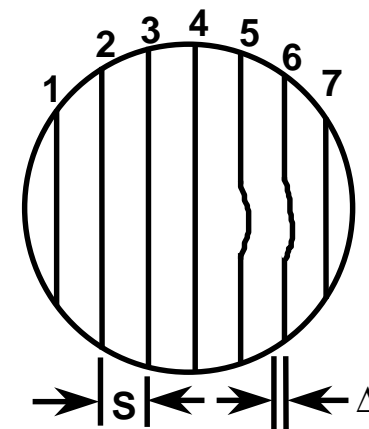
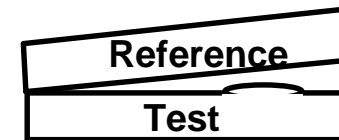
1998 - James C. Wyant

For a given fringe the separation between the two surfaces is a constant.

$$\text{Height error} = (\lambda/2)(\Delta/S)$$



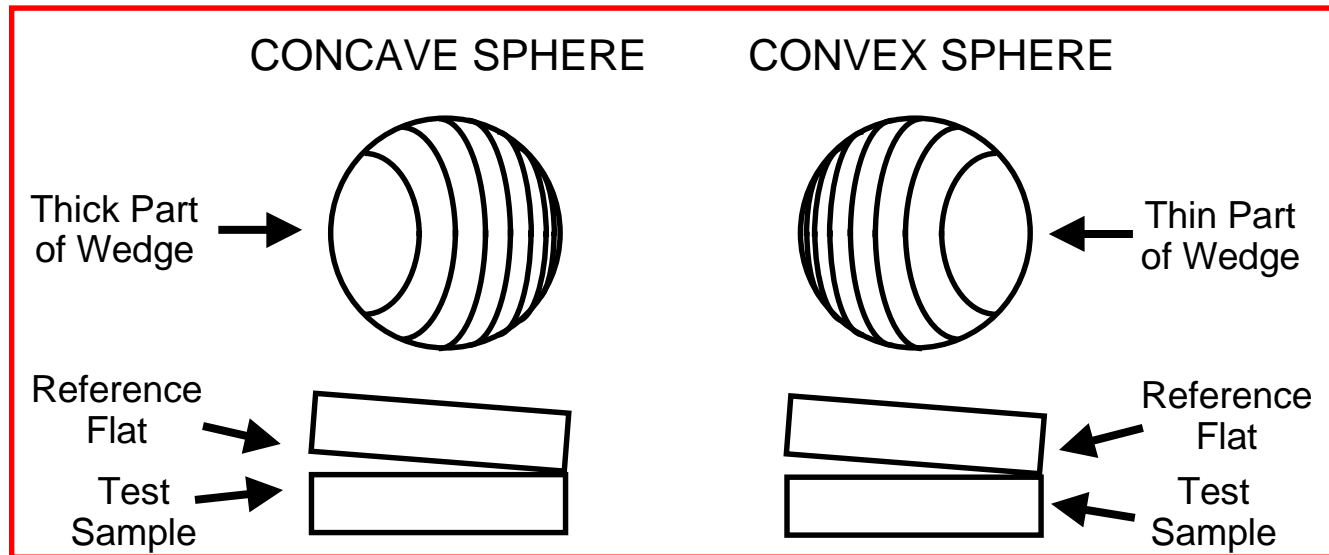
Top View



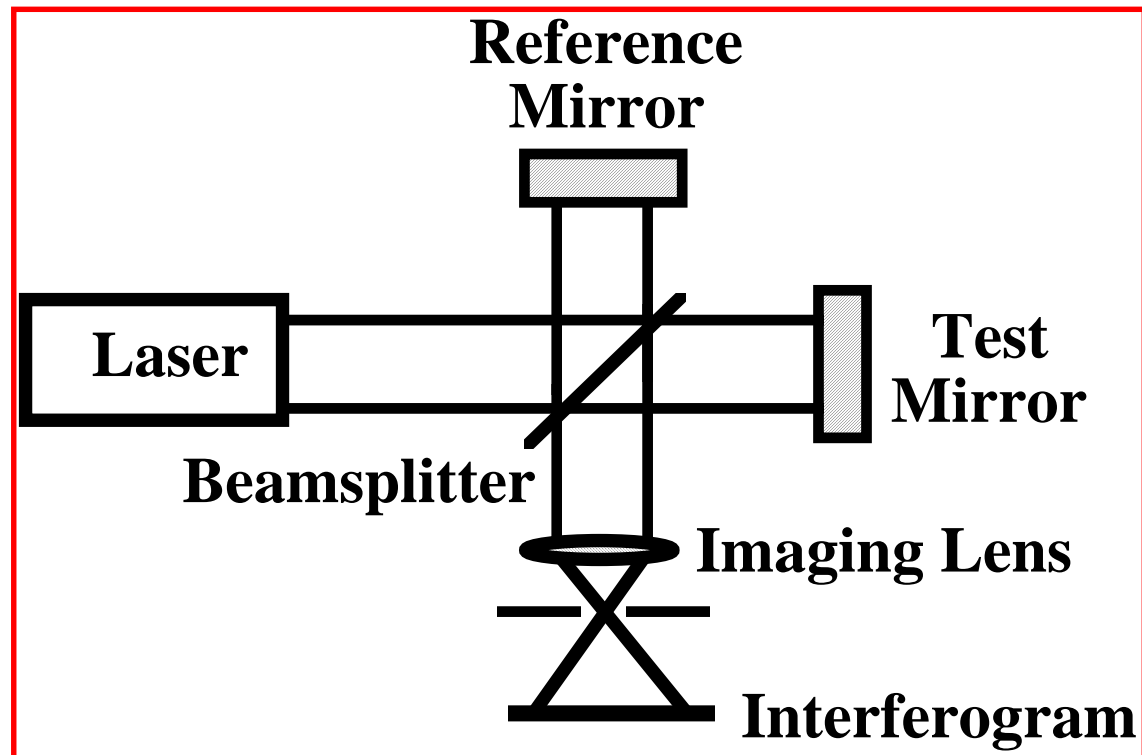
Interferogram

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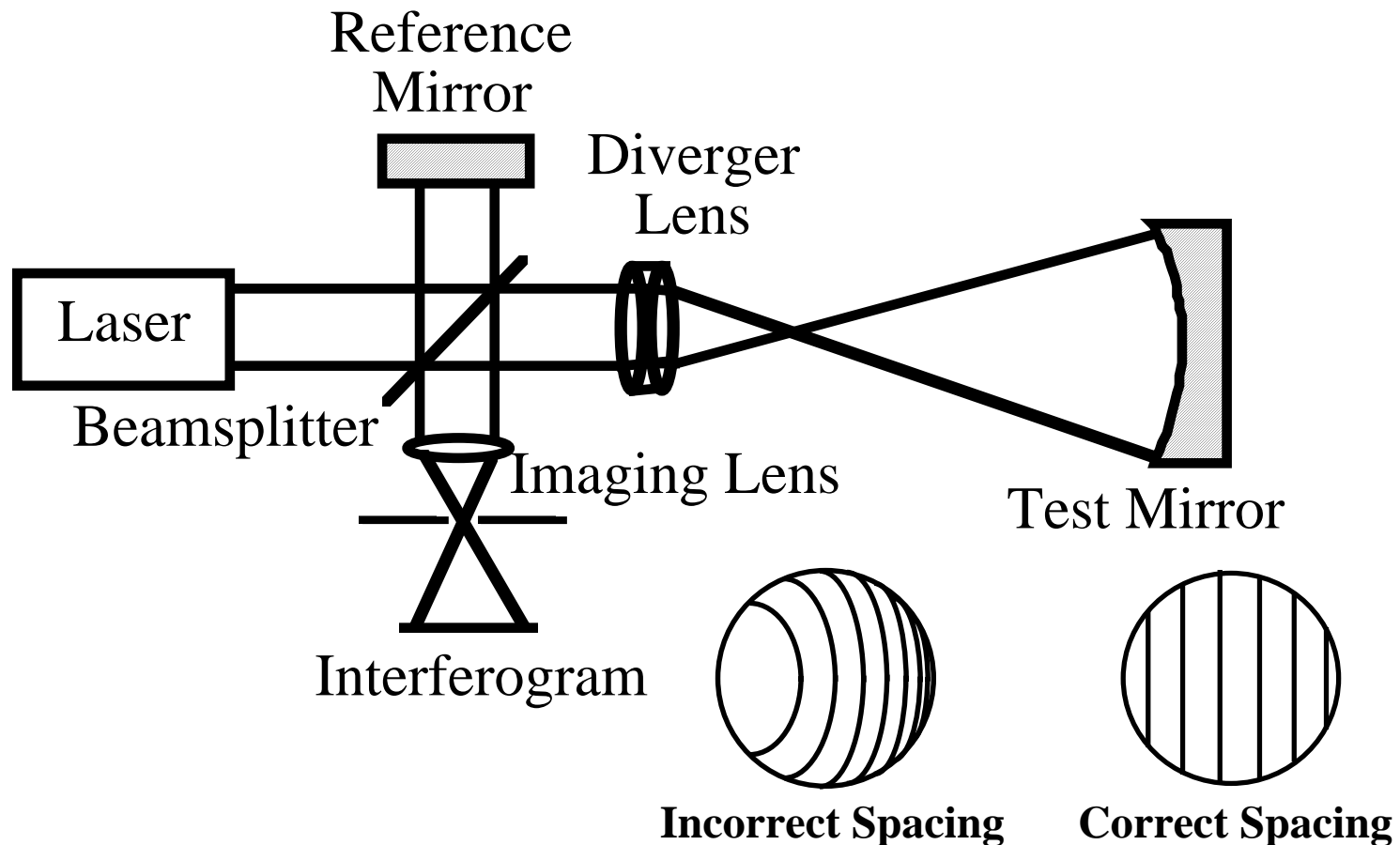
Fizeau Fringes for Concave and Convex Surfaces



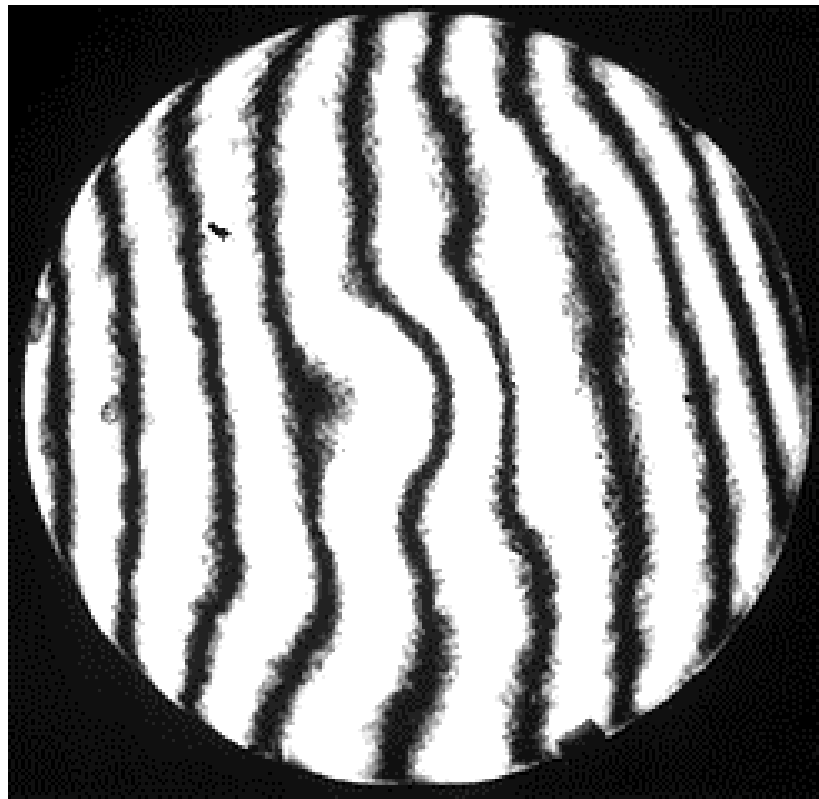
Twyman-Green Interferometer (Flat Surfaces)



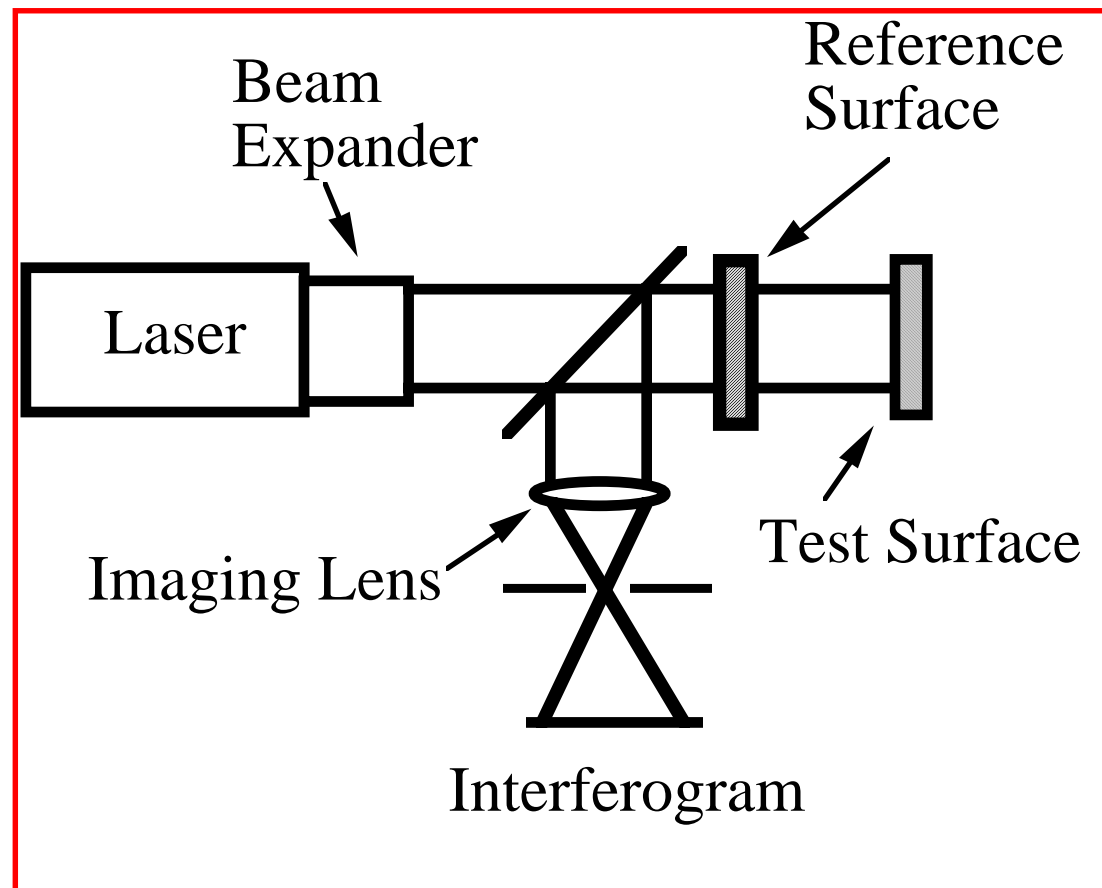
Twyman-Green Interferometer (Spherical Surfaces)



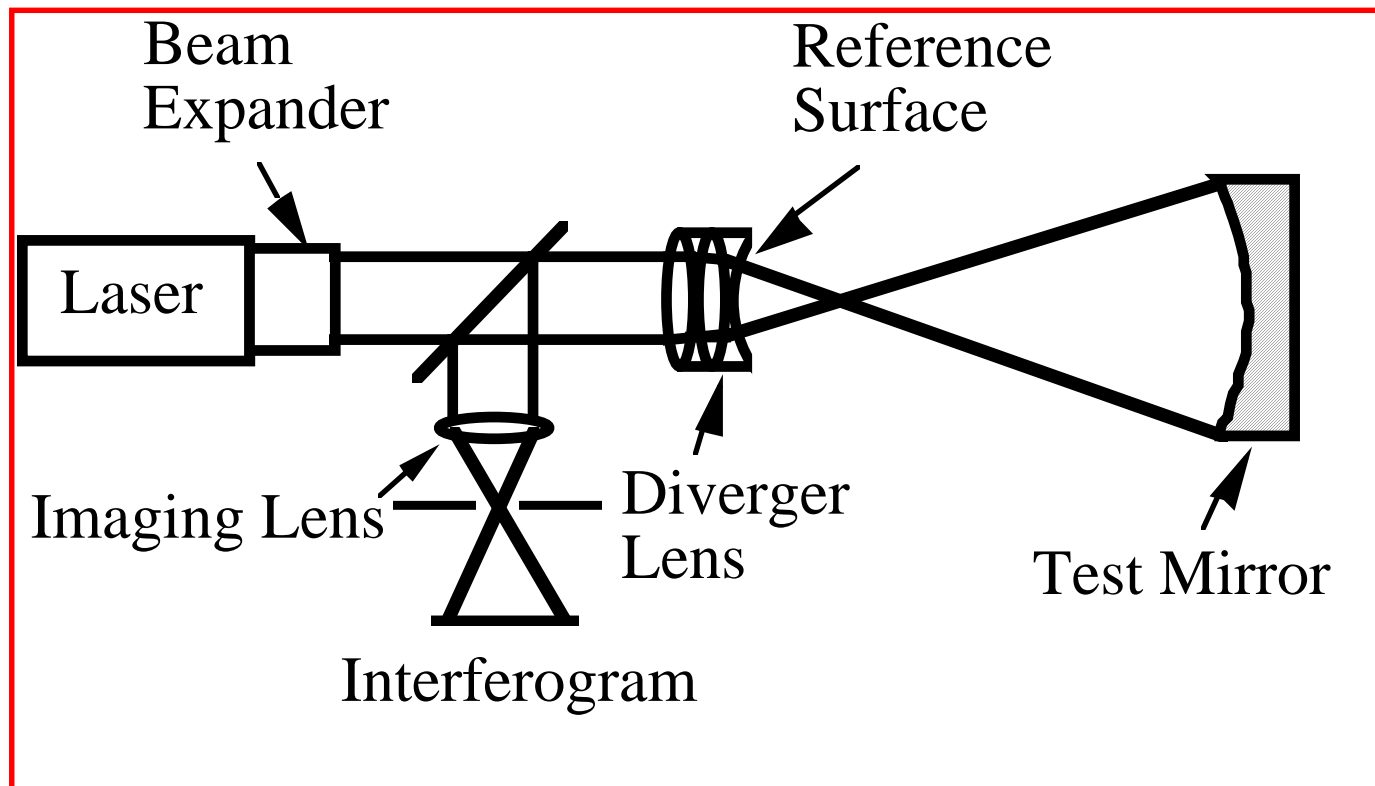
Typical Interferogram



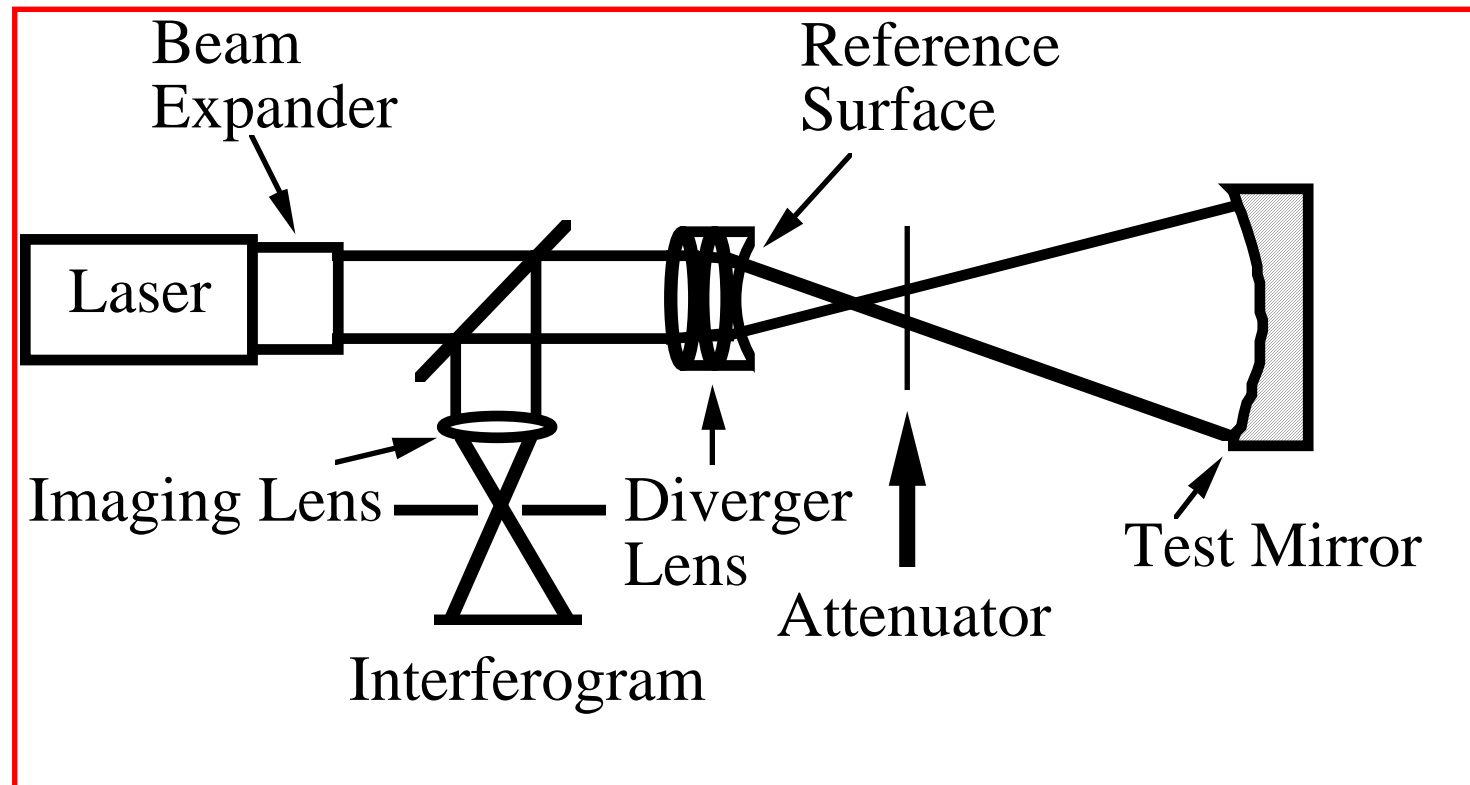
Fizeau Interferometer-Laser Source (Flat Surfaces)



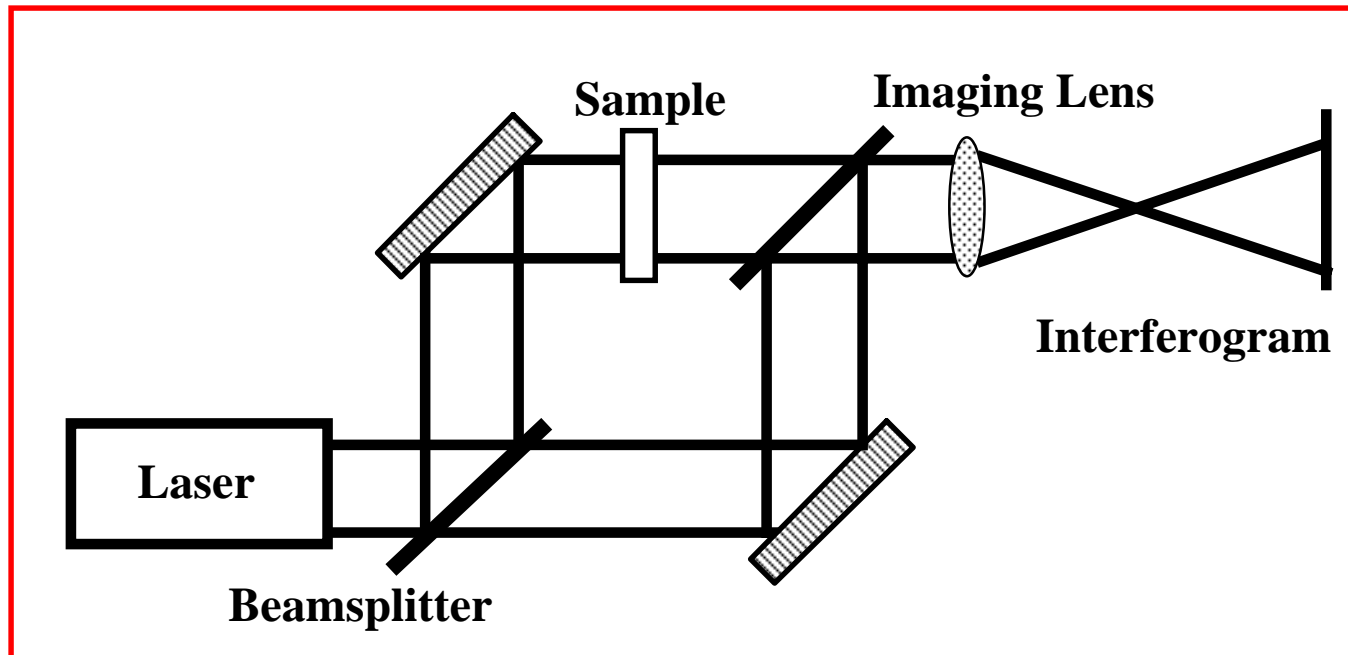
Fizeau Interferometer-Laser Source (Spherical Surfaces)



Testing High Reflectivity Surfaces

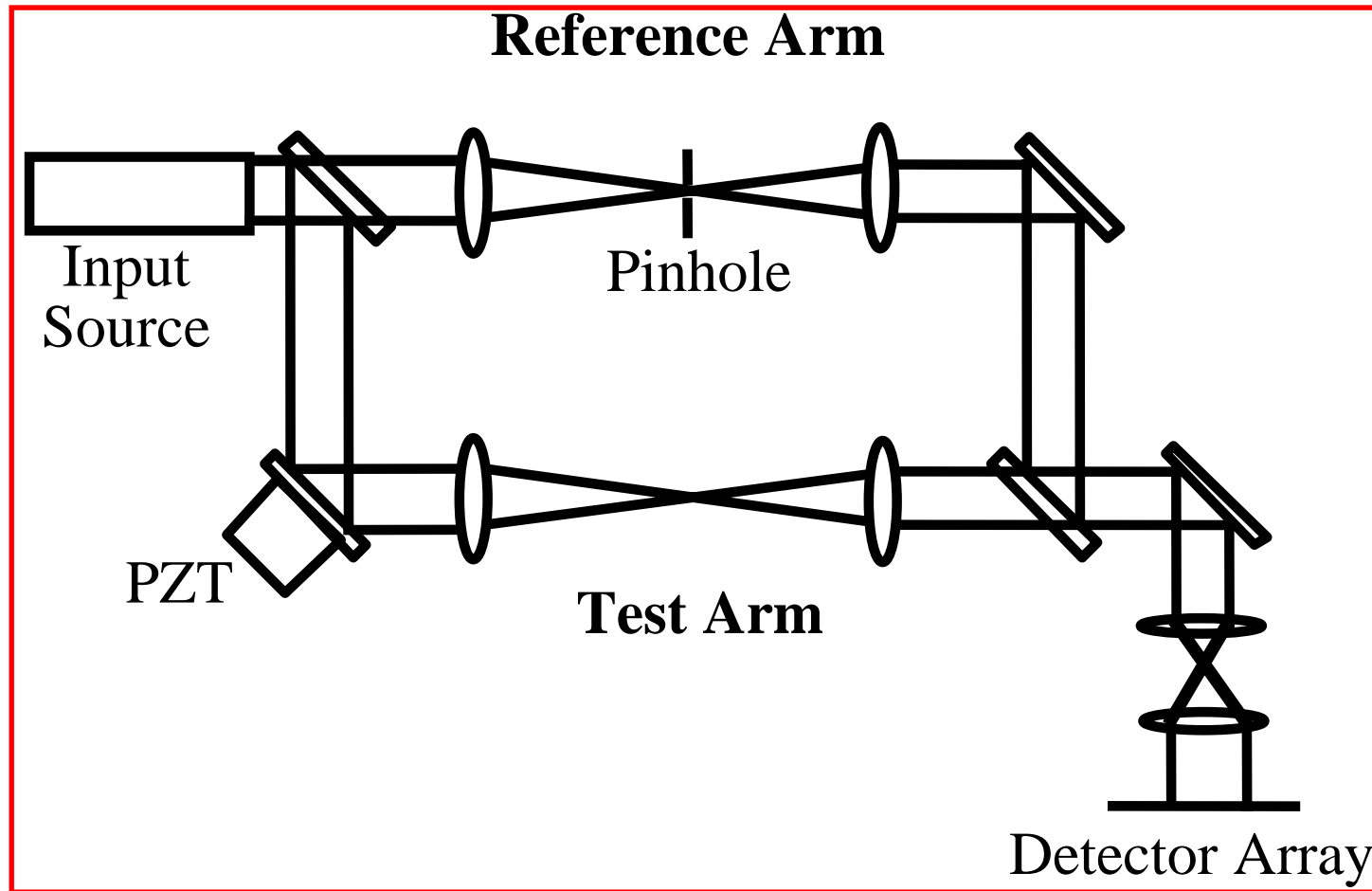


Mach-Zehnder Interferometer

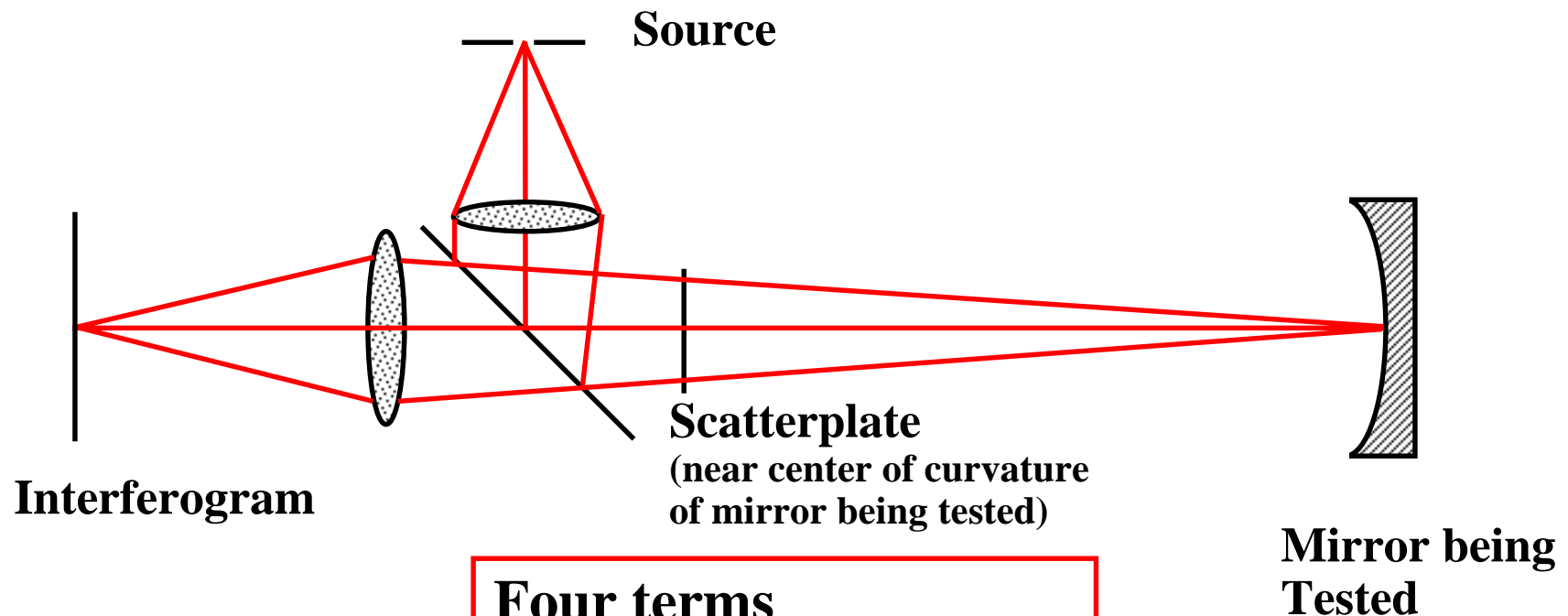


Testing samples in transmission

Laser Beam Wavefront Measurement



Scatterplate Interferometer Setup



Four terms

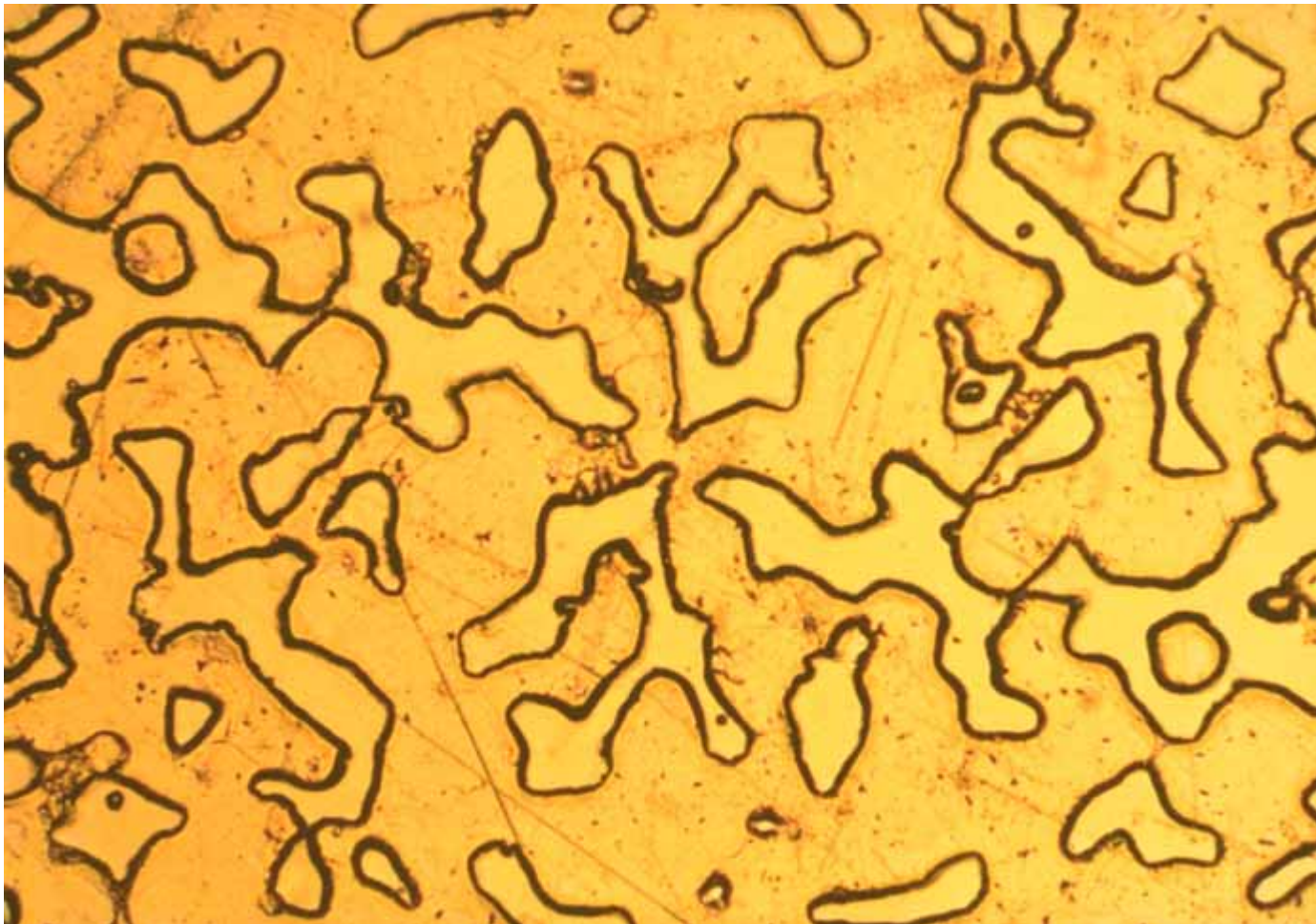
Scattered - Scattered

Scattered - Direct

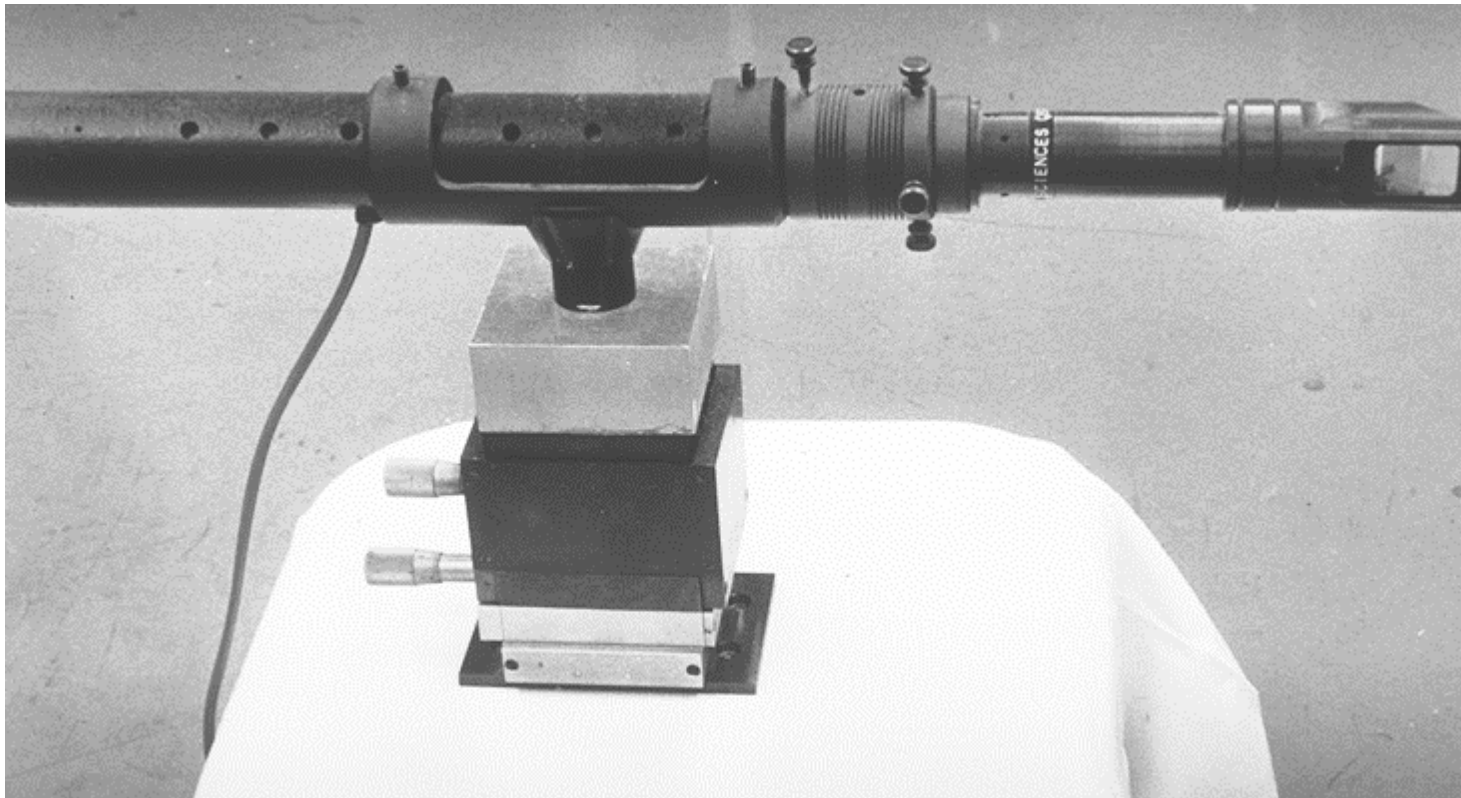
Direct - Scattered

Direct - Direct

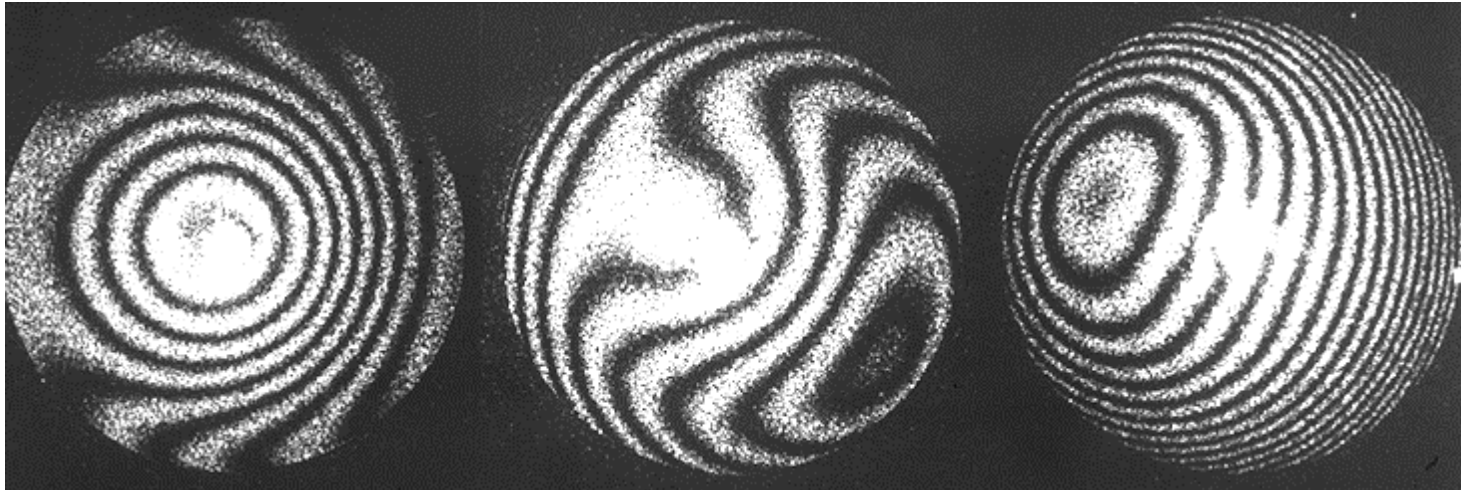
Microscopic Image of Scatterplate



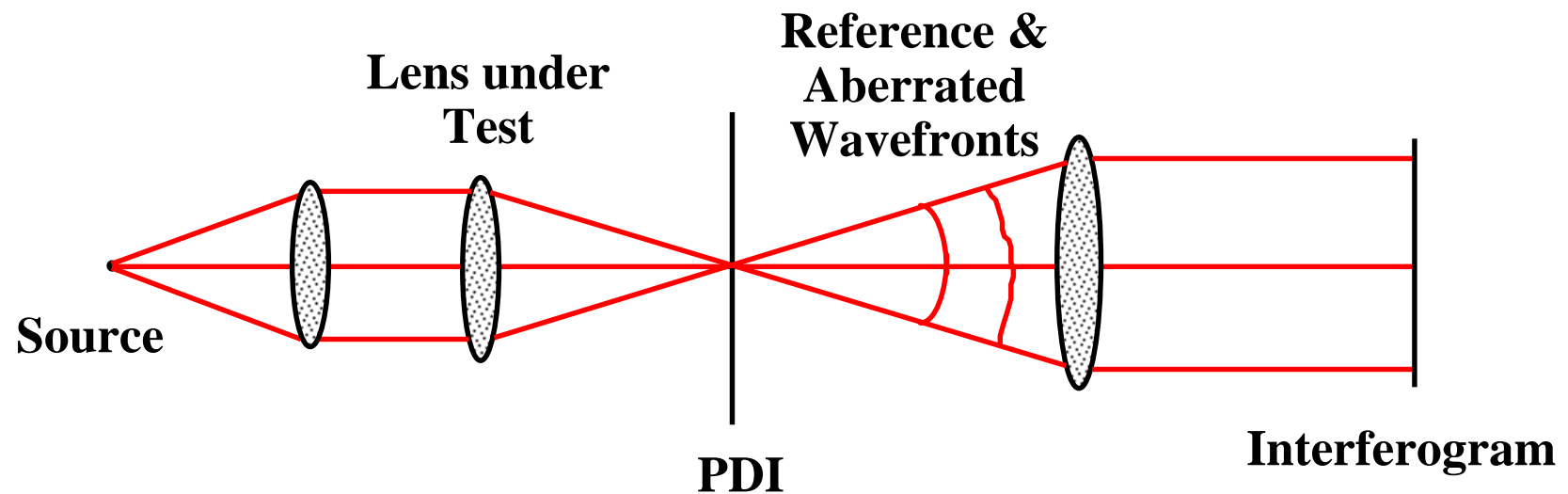
Scatterplate Interferometer



Scatterplate Interferograms

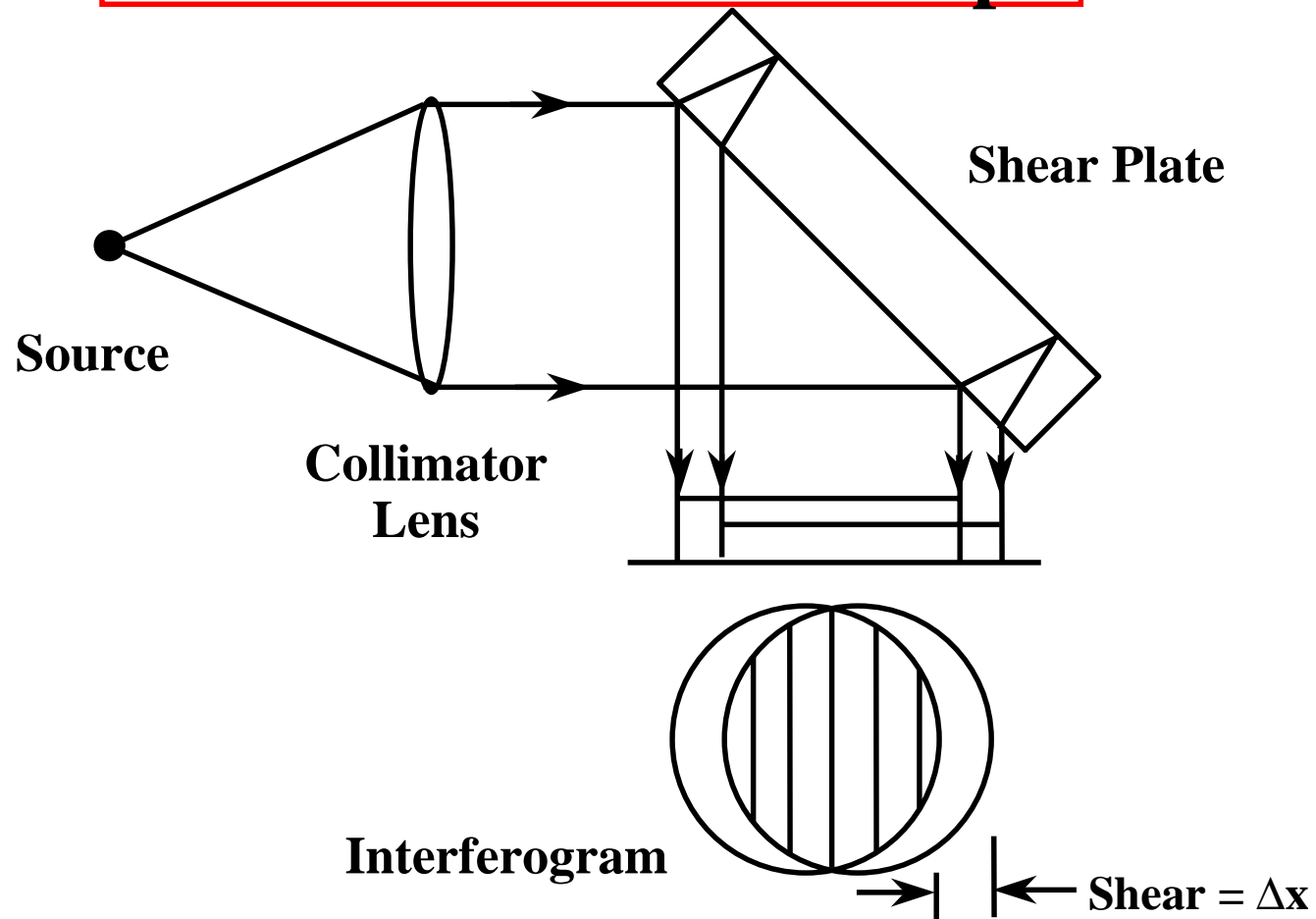


Smartt Point Diffraction Interferometer



Lateral Shear Interferometry

Measures wavefront slope



Lateral Shear Fringes

$\Delta W(x, y)$ is wavefront being measured

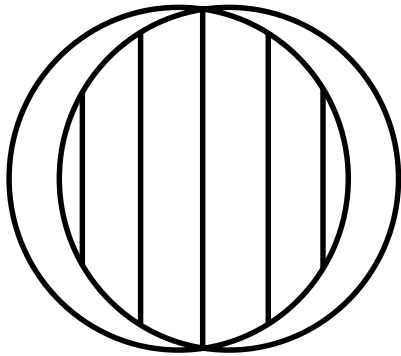
Bright fringe obtained when

$$\Delta W(x + \Delta x, y) - \Delta W(x, y) = m\lambda$$

$$\left(\frac{\partial \Delta W(x, y)}{\partial x} \right)_{\text{Average over shear distance}} (\Delta x) = m\lambda$$

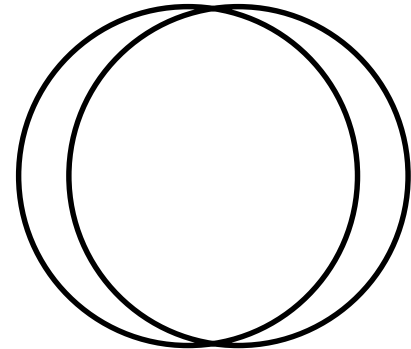
**Measures average value of
slope over shear distance**

Collimation Measurement

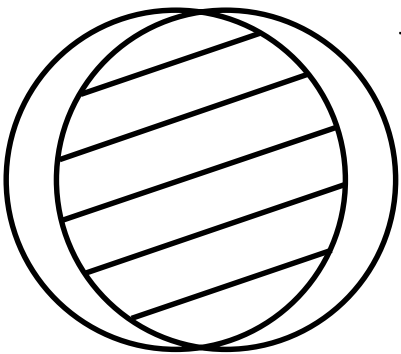


Not collimated

No wedge in shear plate

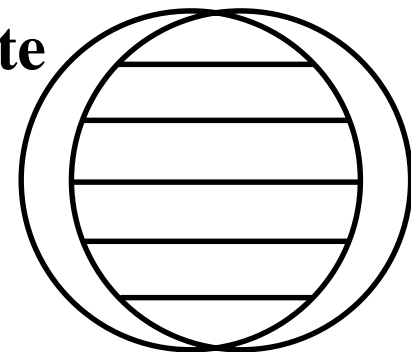


Collimated (one fringe)



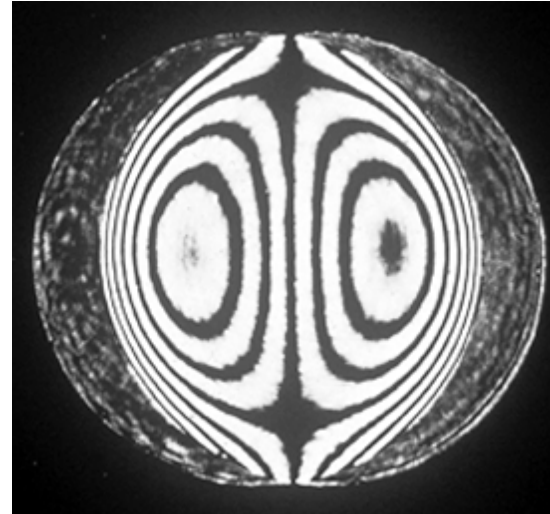
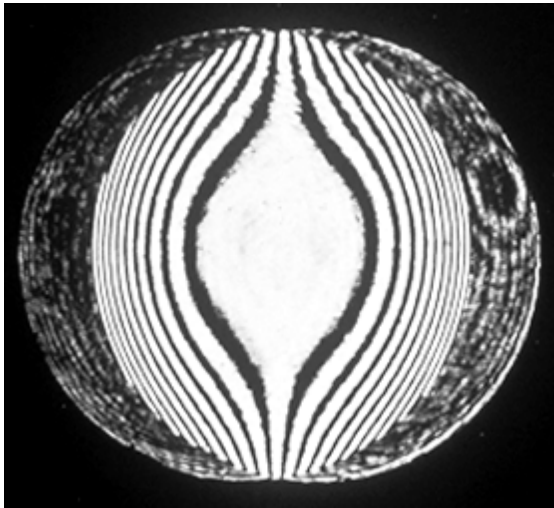
Not collimated

Vertical wedge in shear plate

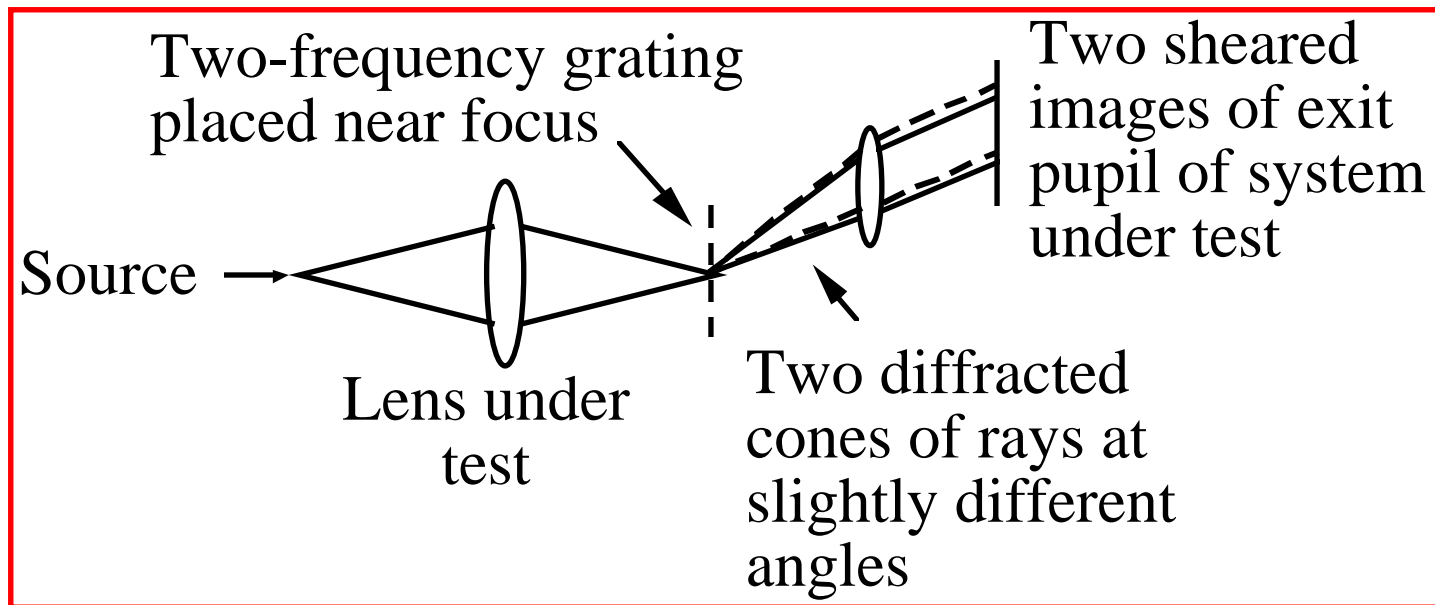


Collimated

Typical Lateral Shear Interferograms

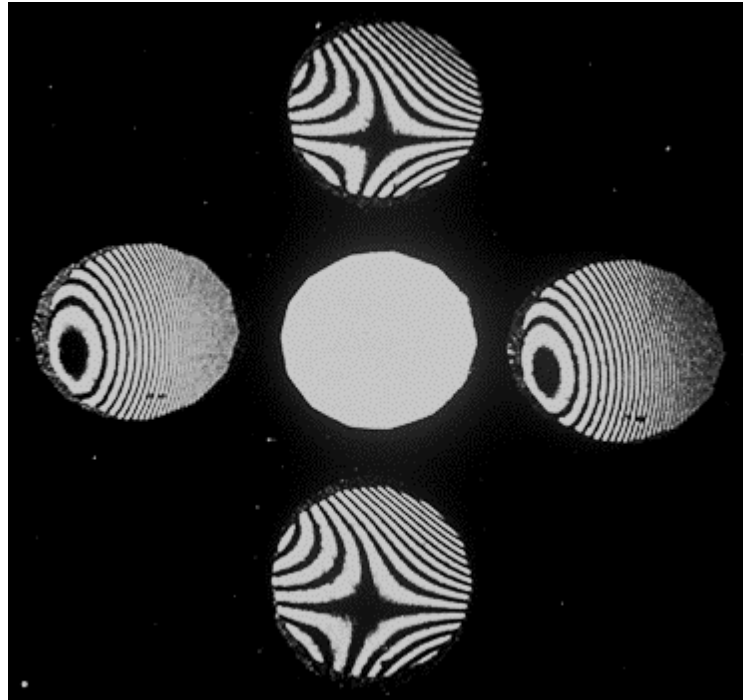


Lateral Shear Interferometer

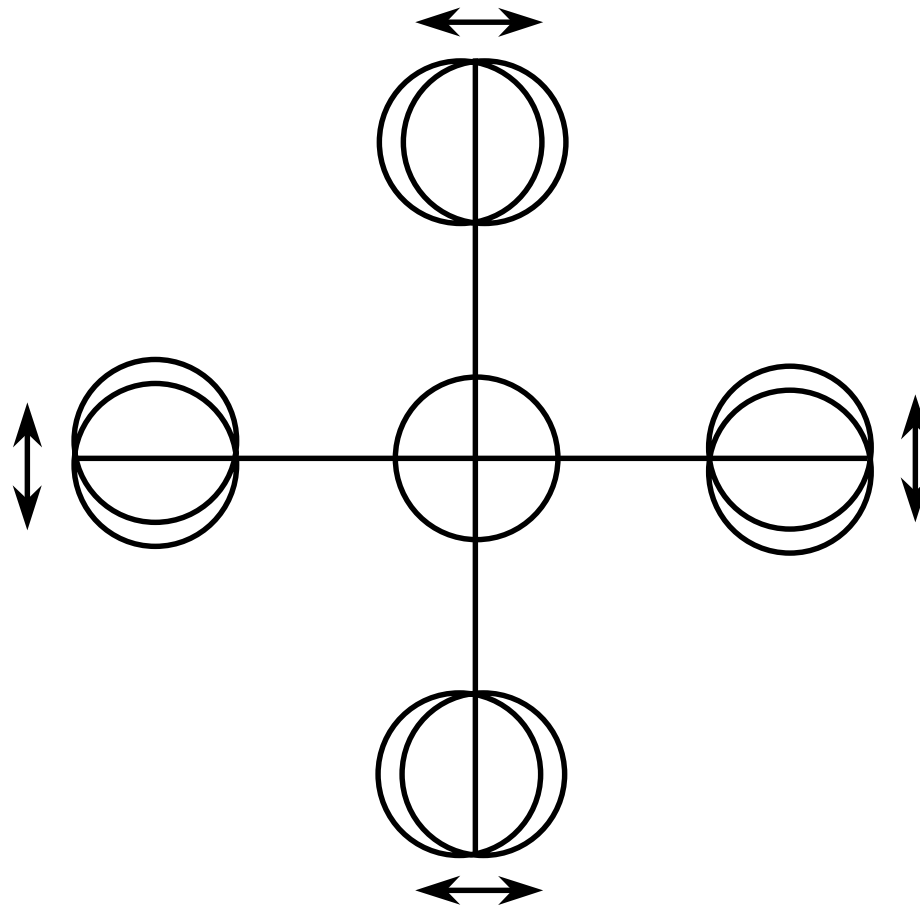


Measures slope of wavefront, not wavefront shape.

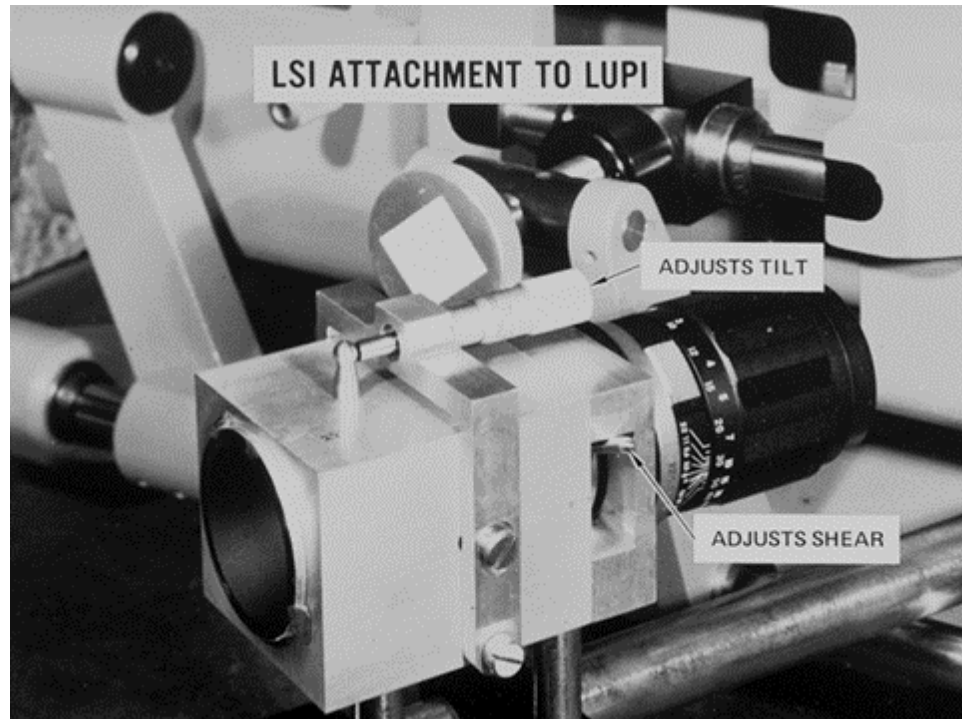
Interferogram Obtained using Grating Lateral Shear Interferometer



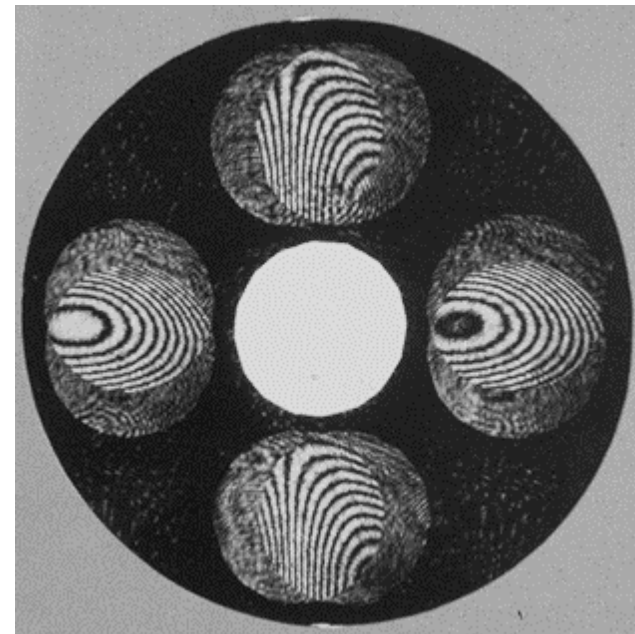
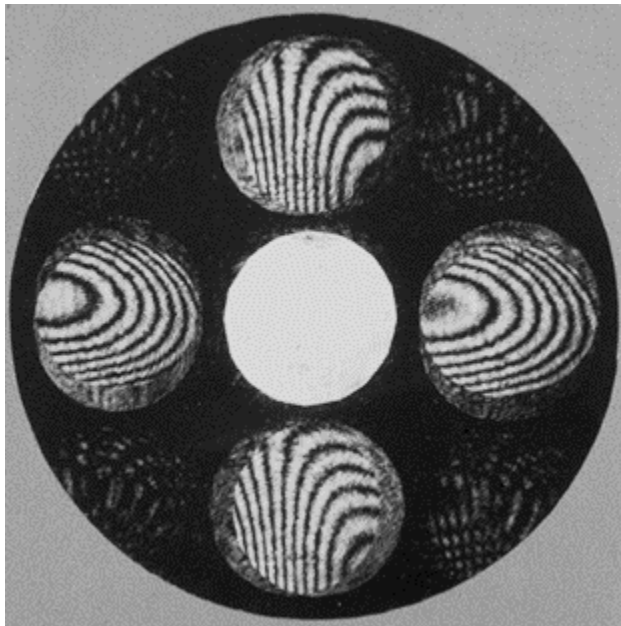
Rotating Grating LSI (Variable Shear)



Rotating Grating LSI

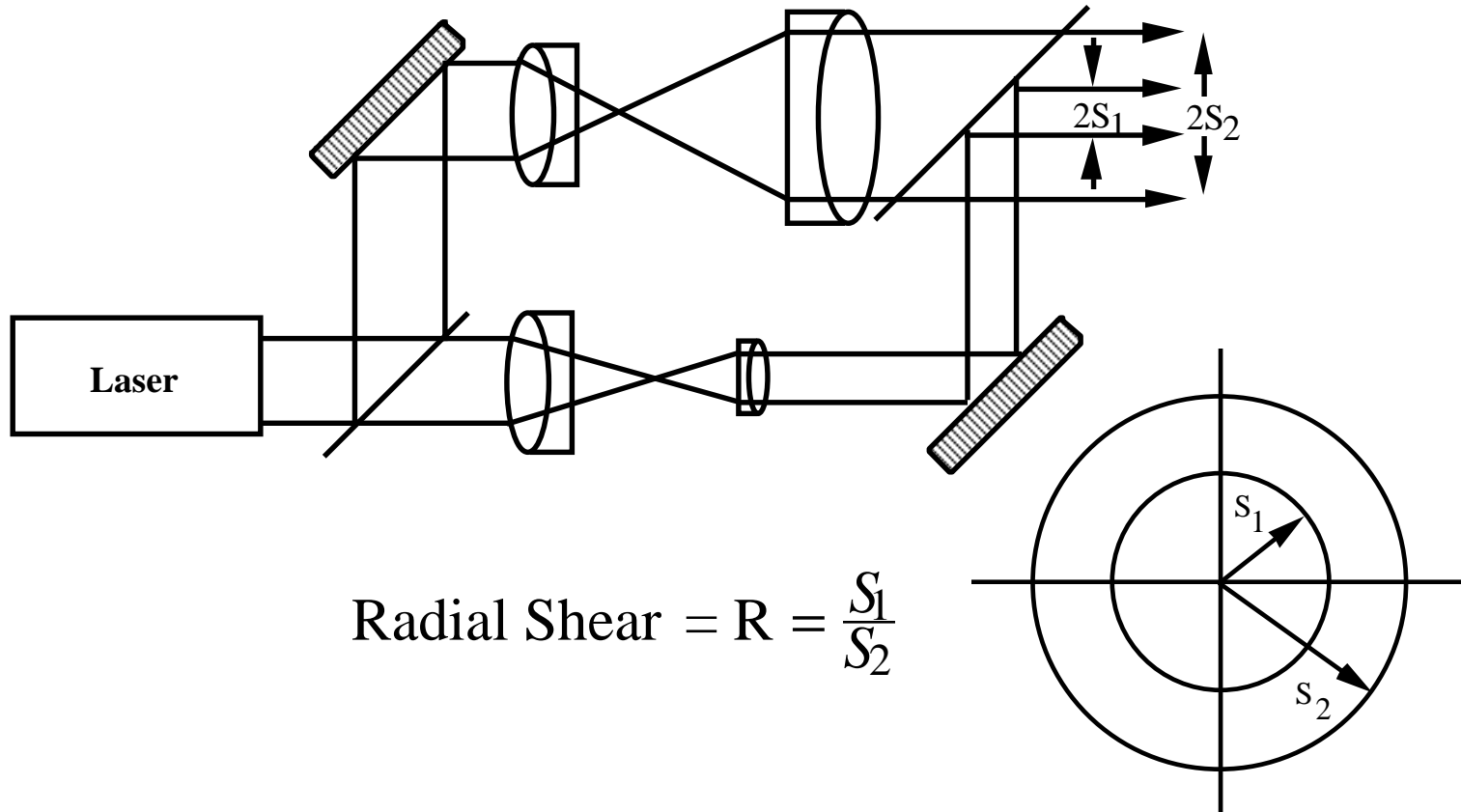


Shearing Interferograms (Different Shear)



Radial Shear Interferometry

Wavefront is interfered with expanded version of itself



Analysis of Radial Shear Interferograms

Wavefront being measured

$$\Delta W(\rho, \theta) = W_{020}\rho^2 + W_{040}\rho^4 + W_{131}\rho^3 \cos \theta + W_{222}\rho^2 \cos^2 \theta$$

Expanded beam can be written

$$\begin{aligned} \Delta W(R\rho, \theta) = & W_{020}(R\rho)^2 + W_{040}(R\rho)^4 + W_{131}(R\rho)^3 \cos \theta \\ & + W_{222}(R\rho)^2 \cos^2 \theta \end{aligned}$$

Hence, a bright fringe is obtained whenever

$$\begin{aligned} \Delta W(\rho, \theta) - \Delta W(R\rho, \theta) = & W_{020}\rho^2(1 - R^2) + W_{040}\rho^4(1 - R^4) \\ & + W_{131}\rho^3(1 - R^3) \cos \theta + W_{222}\rho^2(1 - R^2) \cos^2 \theta \end{aligned}$$

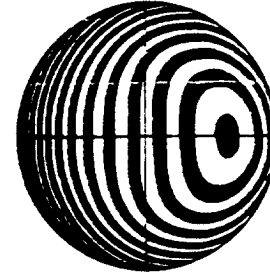
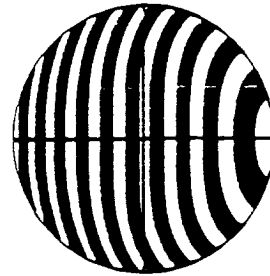
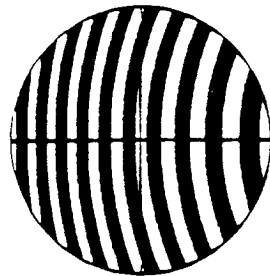
Same as Twyman-Green if divide each coefficient by $(1 - R^n)$

Radial Shear Interferogram

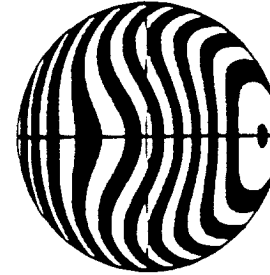
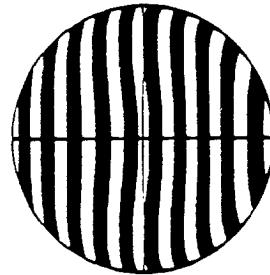
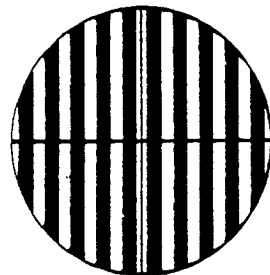
- **Variable Sensitivity Test**
 - **Large shear - results same as for Twyman-Green**
 - **Small shear - Low sensitivity test**

Interferograms, Spherical Aberration

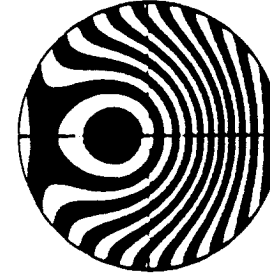
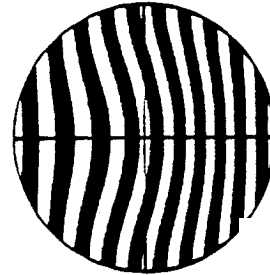
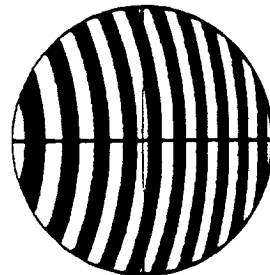
Paraxial
Focus



Mid
Focus



Marginal
Focus



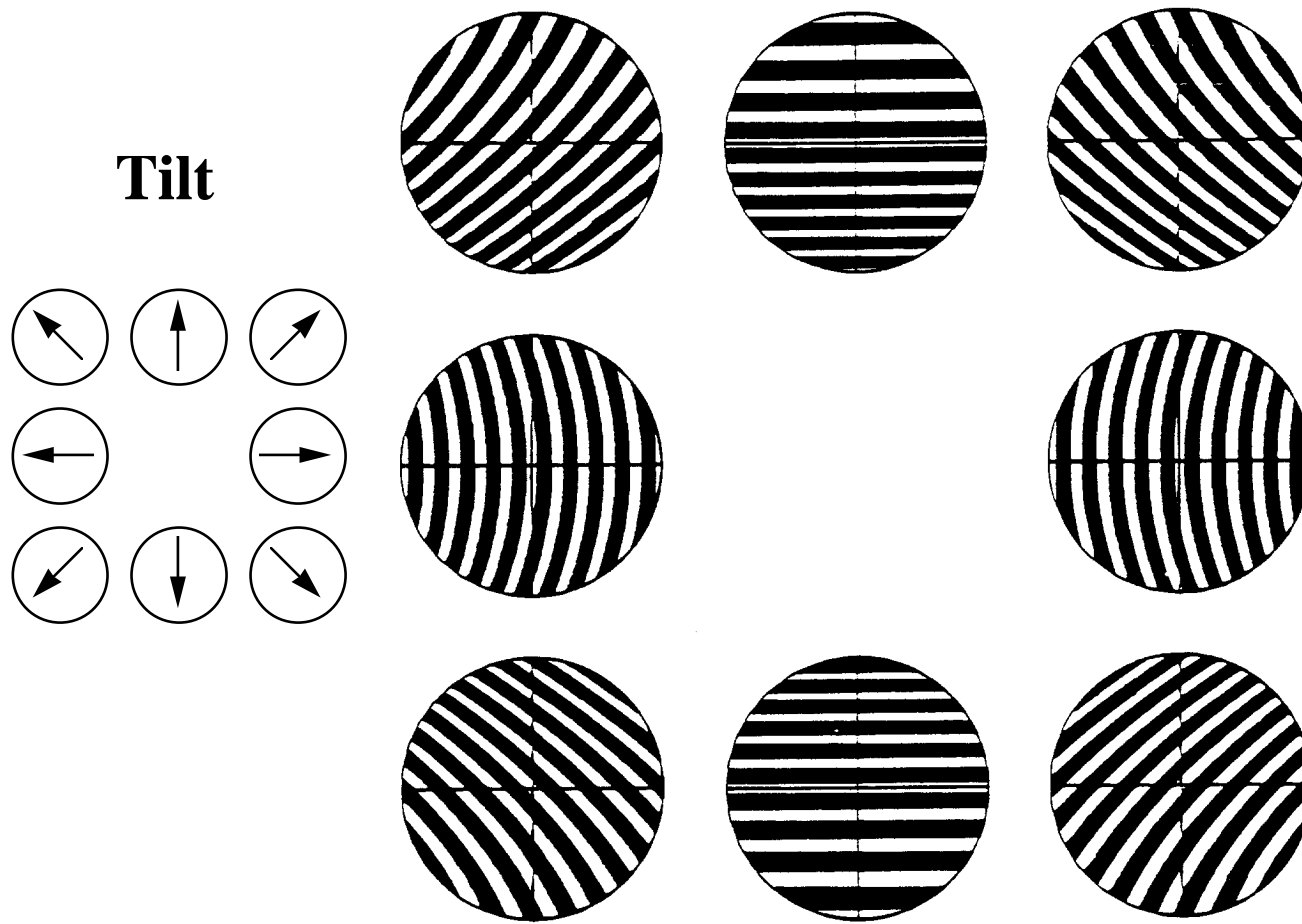
No Aberration
Focal Shift

Small Spherical
Aberration

Larger Spherical
Aberration

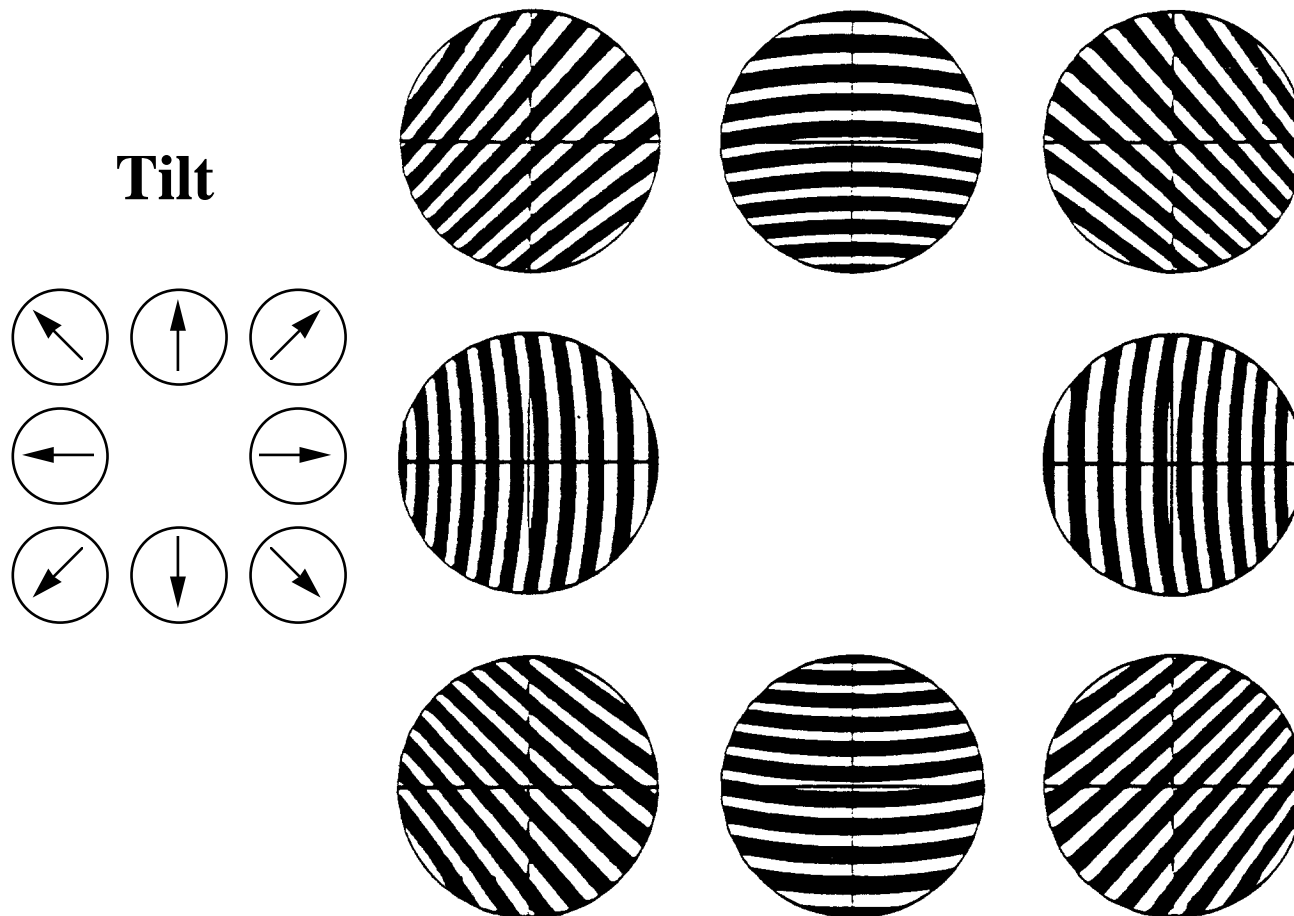
Interferograms

Small Astigmatism, Sagittal Focus

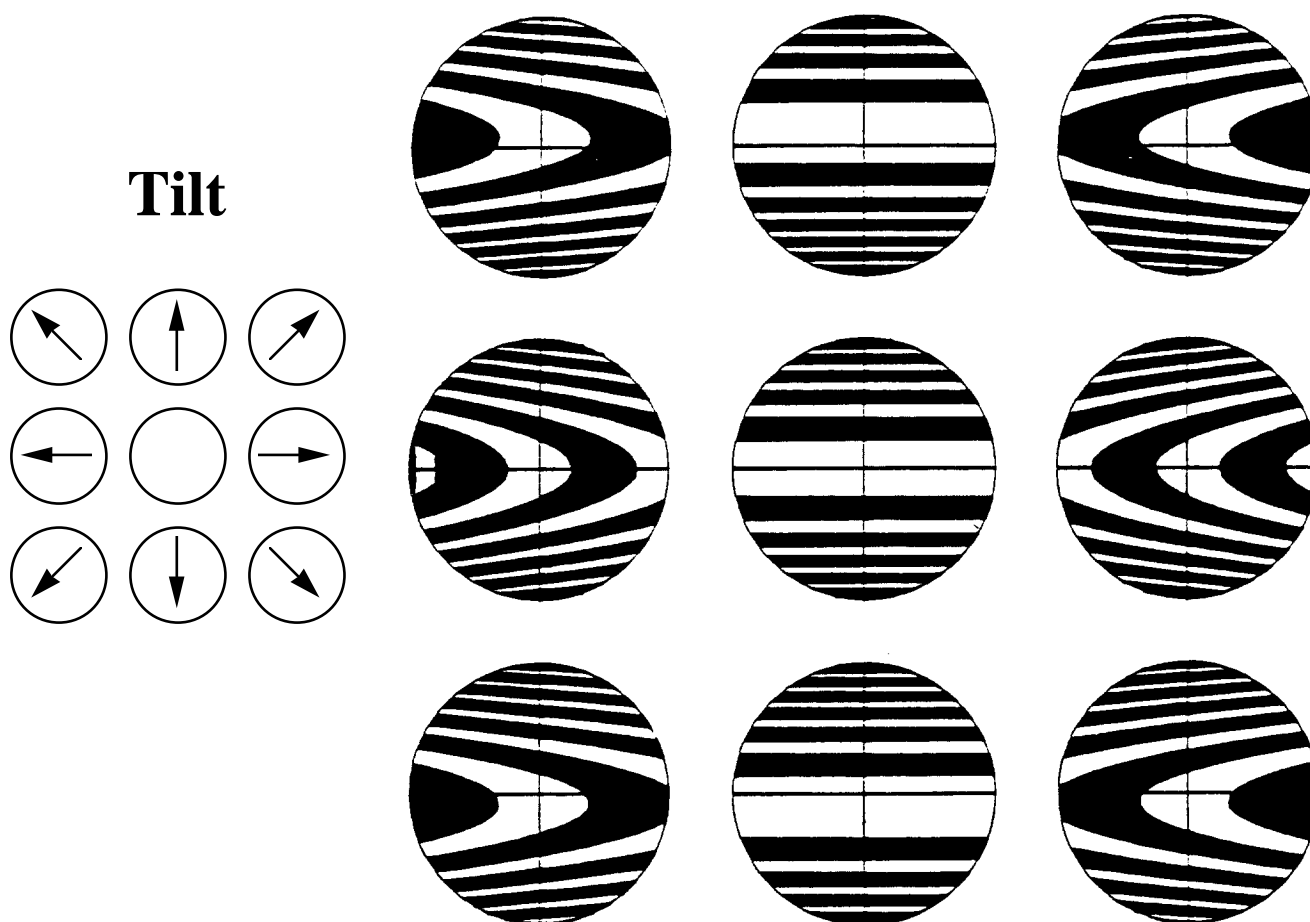


Interferograms

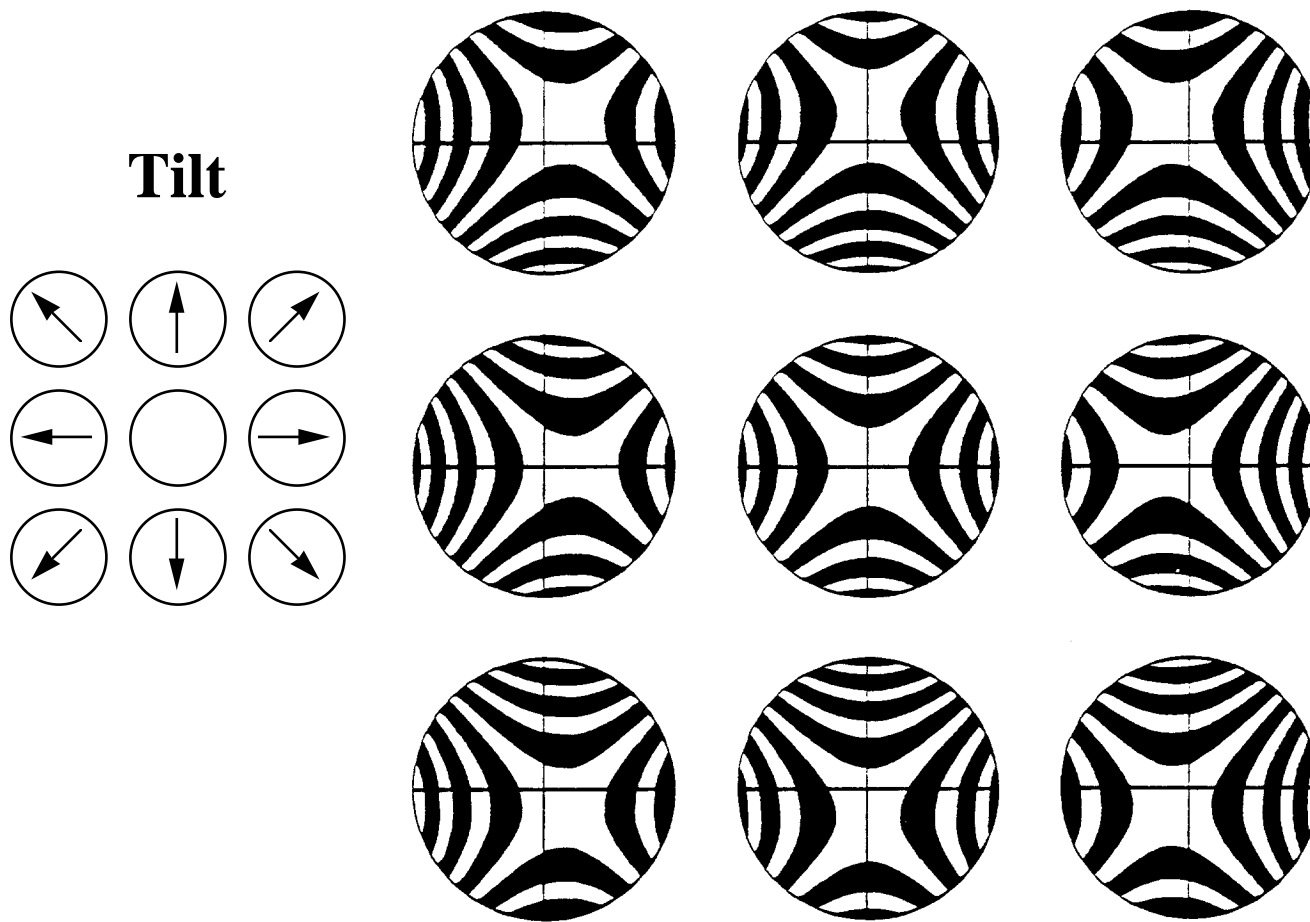
Small Astigmatism, Medial Focus



Interferograms, Large Astigmatism, Sagittal Focus, Small Tilt



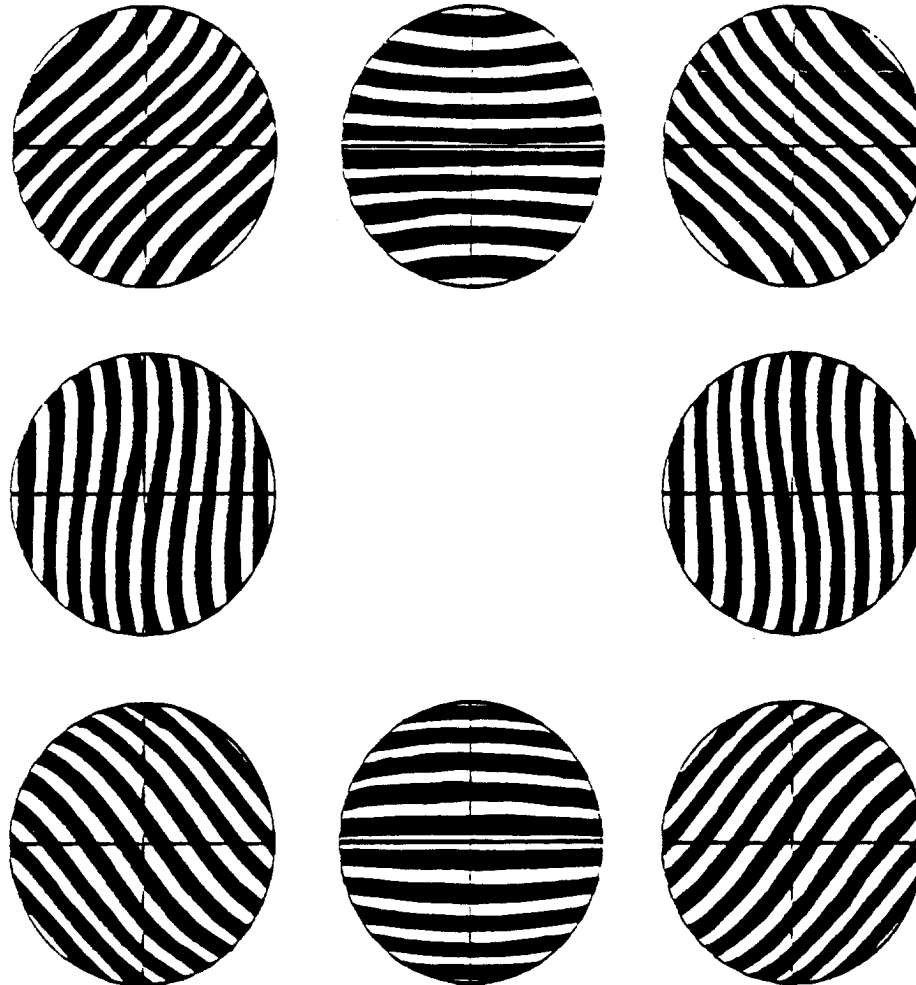
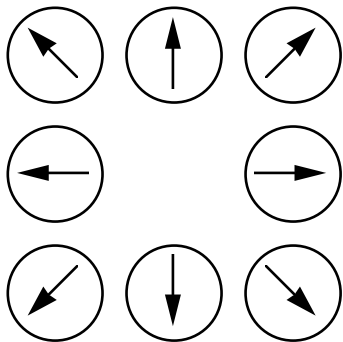
Interferograms, Large Astigmatism, Medial Focus, Small Tilt



Interferograms

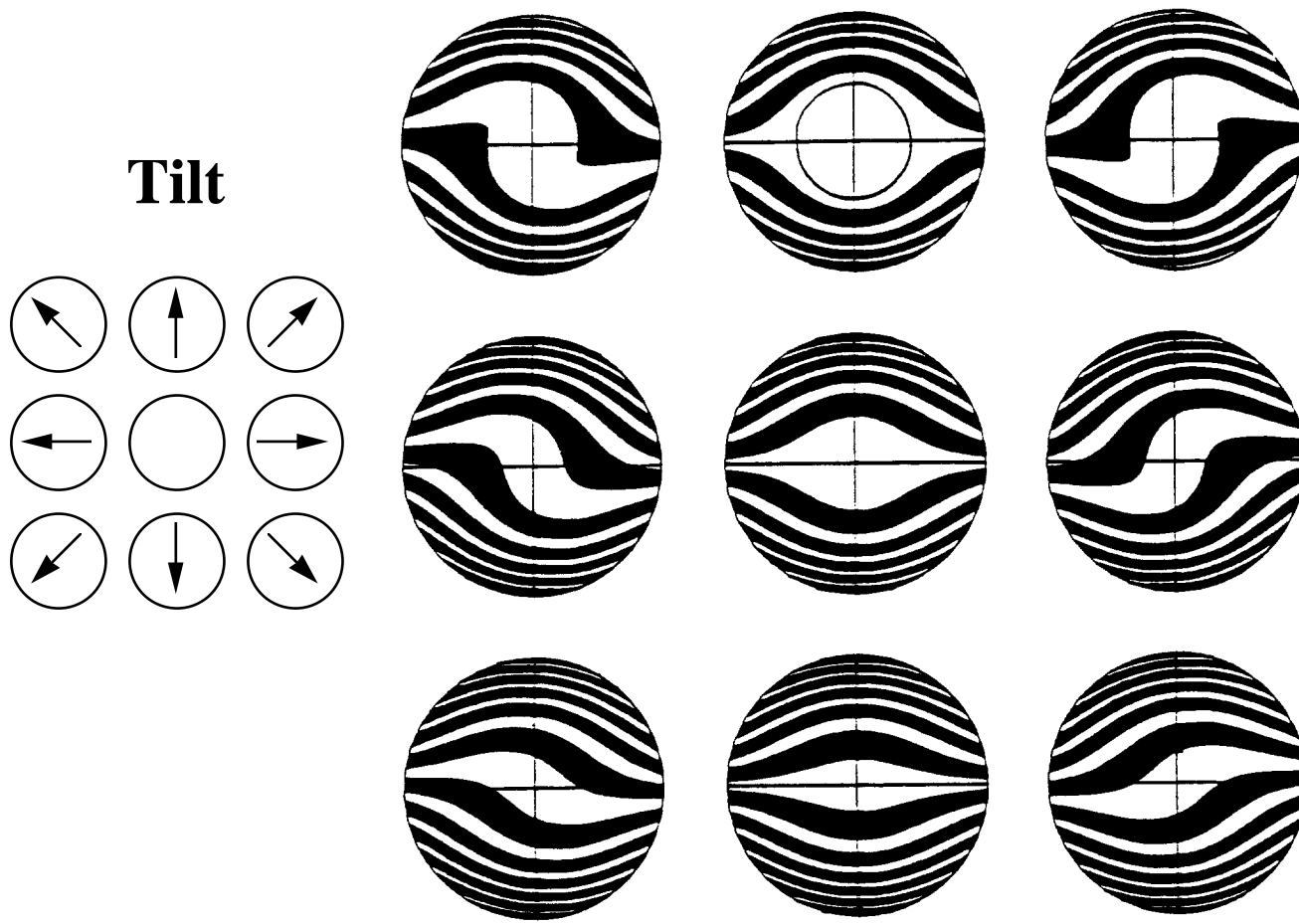
Small Coma, Large Tilt

Tilt



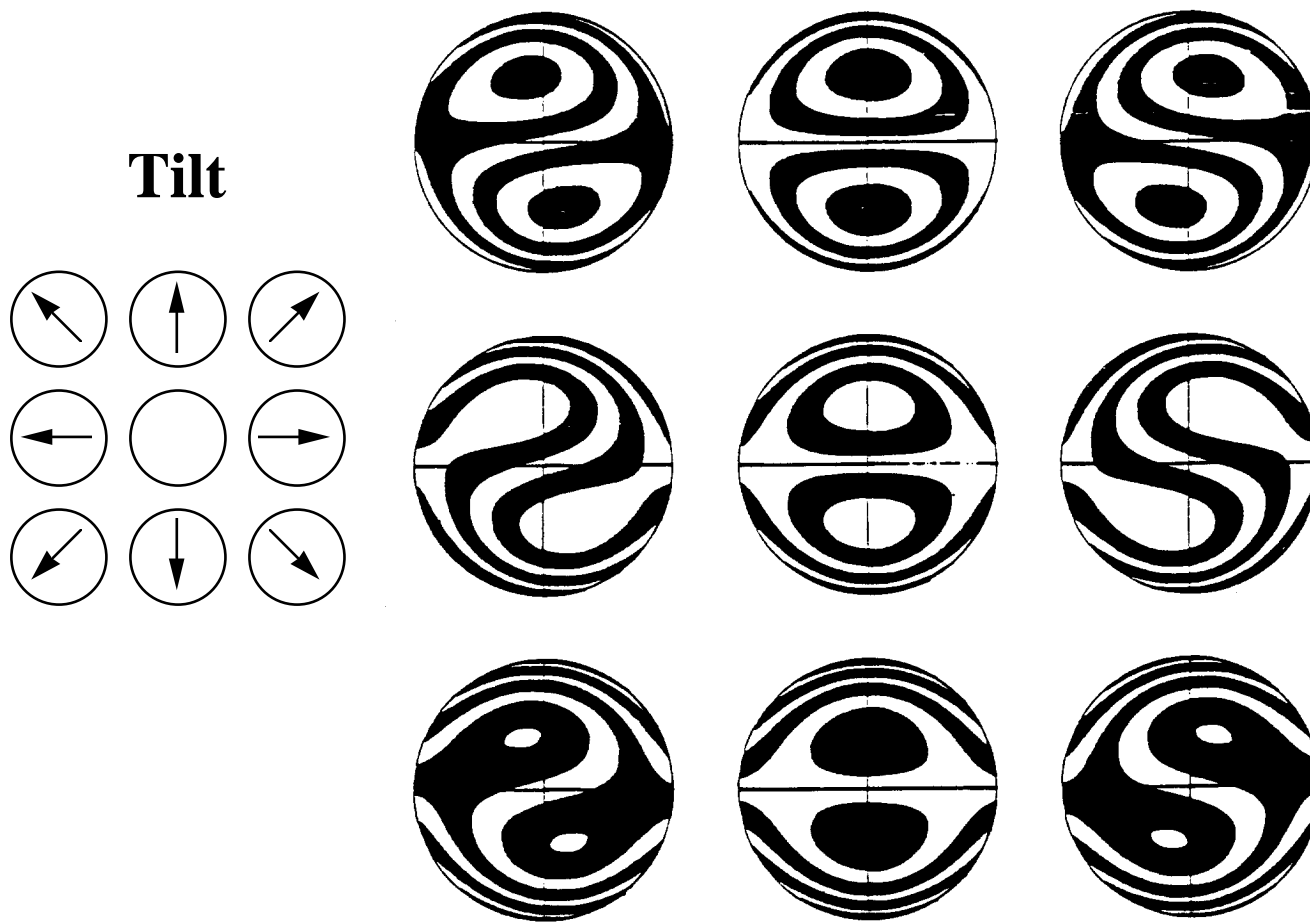
Interferograms

Large Coma, Small Tilt



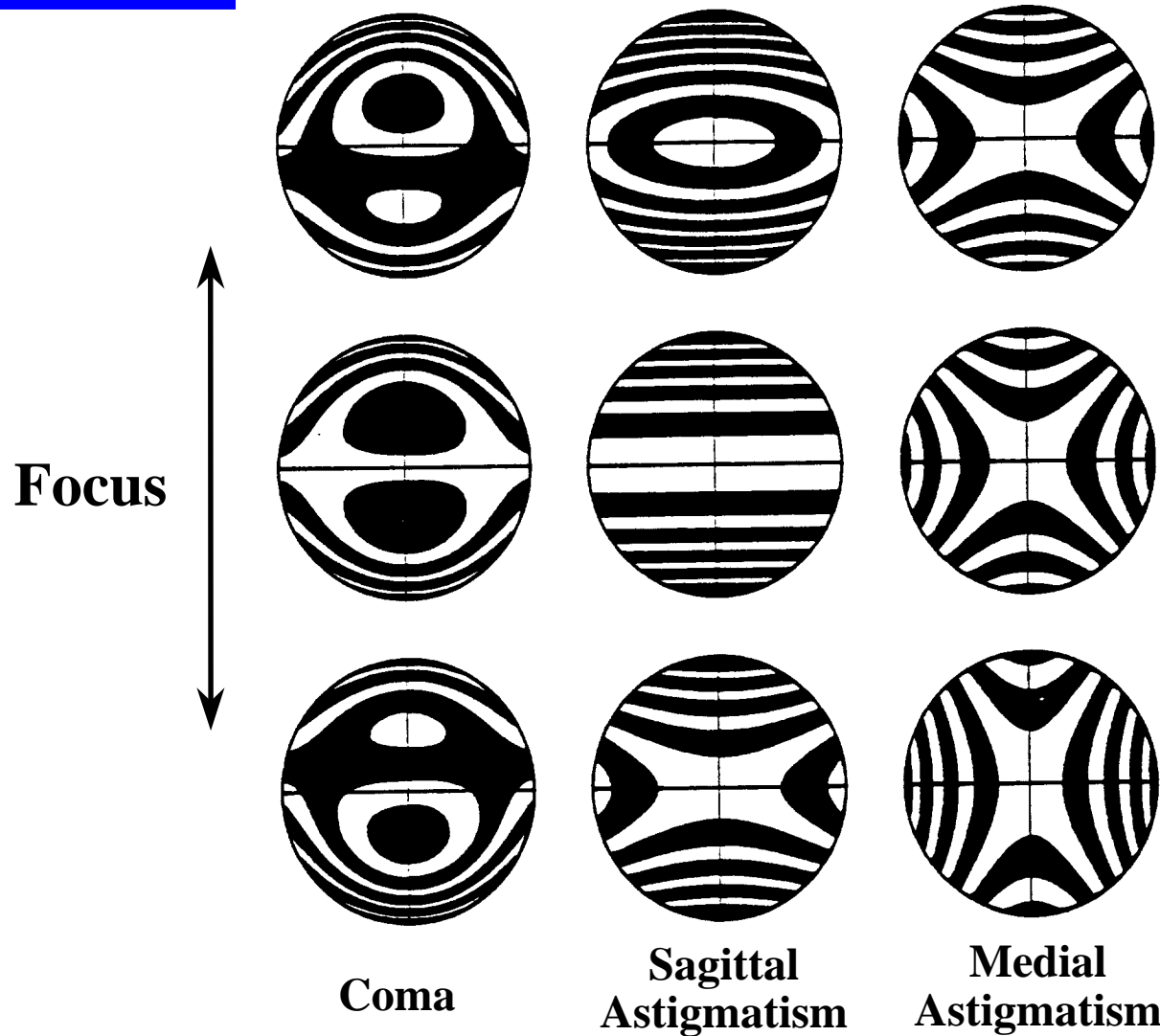
Interferograms

Large Coma, Large Tilt

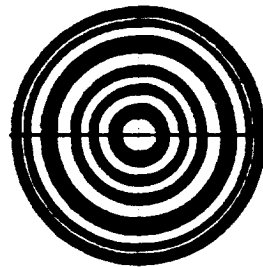


Interferograms

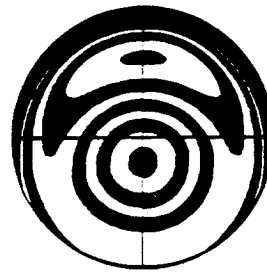
Small Focal Shift



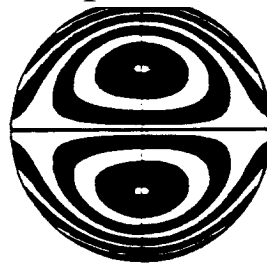
Interferograms Combined Aberrations



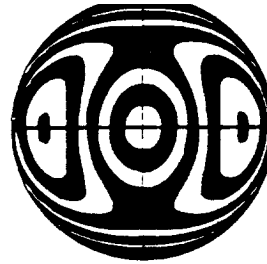
Spherical



Sph + Coma



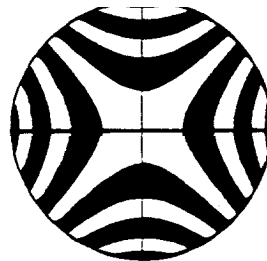
Coma



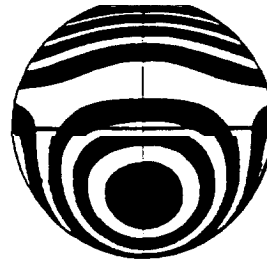
Sph + Astig



Sph + Coma
+ Astig



Astig



Coma + Astig

**All wavefronts have
 1λ rms departure
from best-fitting
reference sphere.**